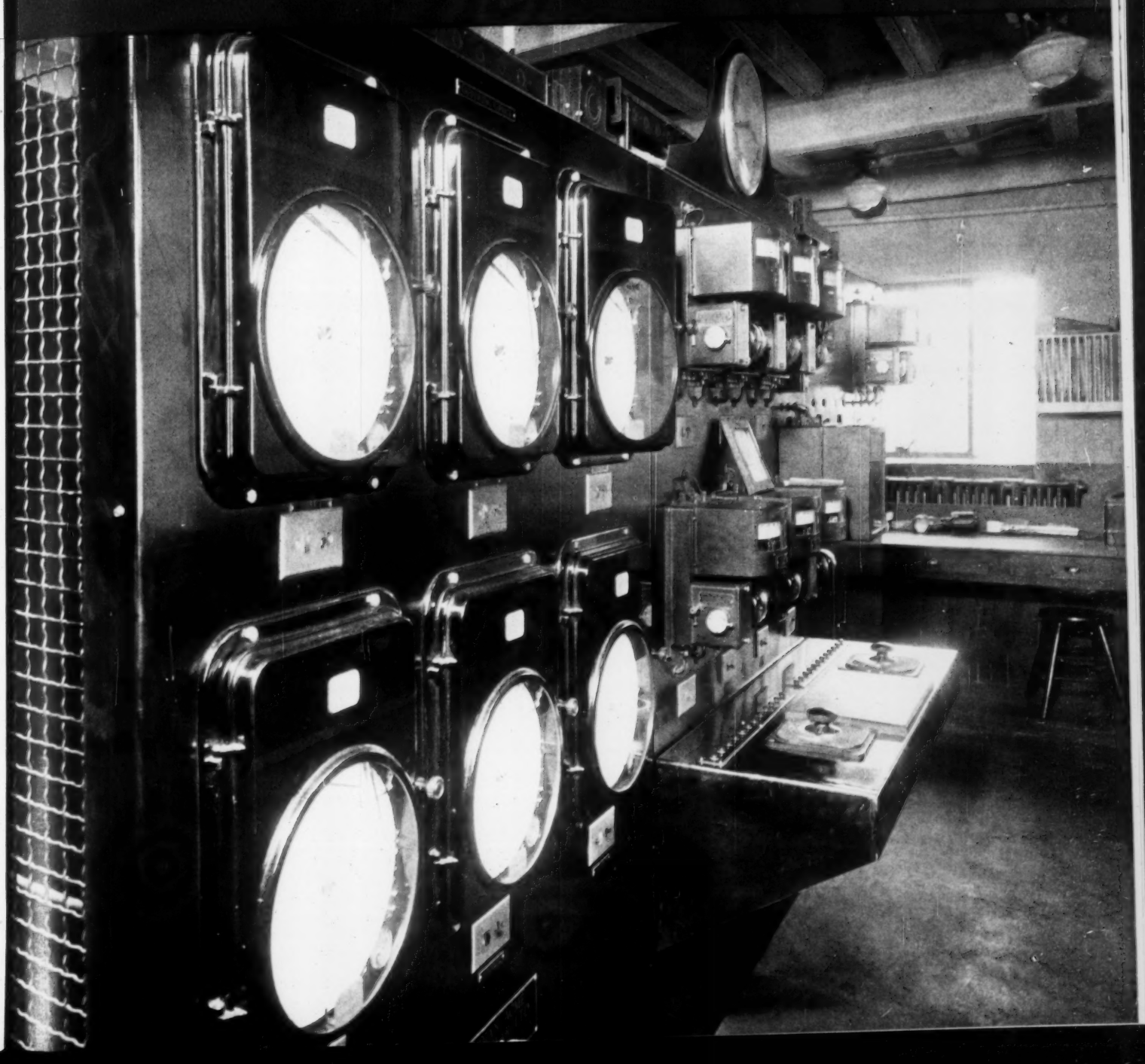
Instruments

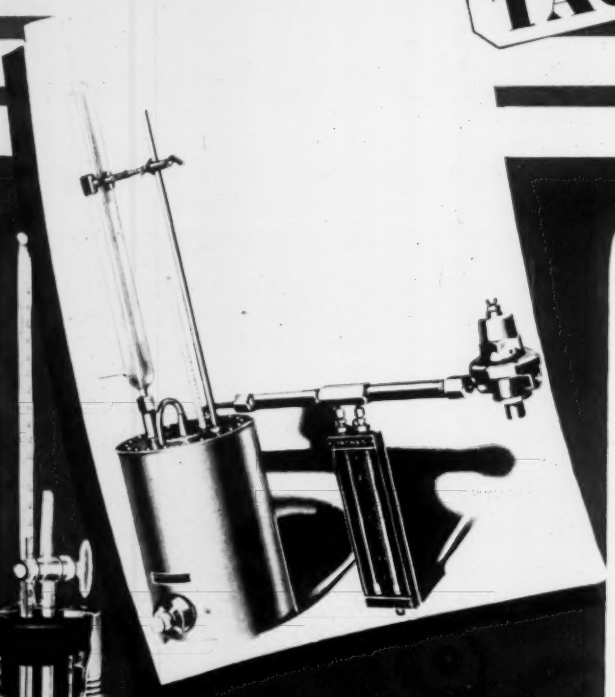
THE MAGAZINE OF Measurement and Control

Vol. 11
DEC.
1938
No. 12



Gum in Gasoline

TAG OFFERS IMPROVED APPARATUS GUM TESTS and a NEW INSTRUM FOR DETERMINING ACID HEAT



Wherever petroleum products are tested, TAG OIL TESTING INSTRUMENTS are accepted as standard. . . Thus, TAG's announcement of improved apparatus for determining preformed and potential gum, and for indicating the acid heat of aviation and motor gasoline is especially significant to all manufacturers, marketers and users of motor fuel.

Shown in order by the illustrations on this page are—

No. 1—TAG A.S.T.M. (Serial D381-36) Single Unit Preformed Gum Apparatus. The results obtained by this standard method are indicative of the amount of gum deposition which may take place in service if the motor fuel is used immediately. It is not intended to indicate the gum stability of motor fuel upon storage. The apparatus meets all A.S.T.M. requirements.

No. 2—TAG A.S.T.M. (Serial D481-38T) Acid Heat Apparatus. A method suitable for determining the acid heat of aviation and motor gasoline. The method employed is indicative of the amount of unsaturated hydrocarbons in the gasoline that are reactive with sulphuric acid under the conditions of the test.

No 3—TAG Potential Gum Apparatus. Supplementing the Preformed Gum apparatus described above, this "Breakdown" test measures the time during which gasoline resists appreciable chemical changes when exposed to an atmosphere of oxygen under specified conditions. It has been found possible to predict, with a reasonable degree of accuracy, by means of this accelerated oxidation method, variations in the periods of gum stability of the gasoline.

The new TAG Recording Pressure Gage shown has been found to be an essential accessory to this apparatus.

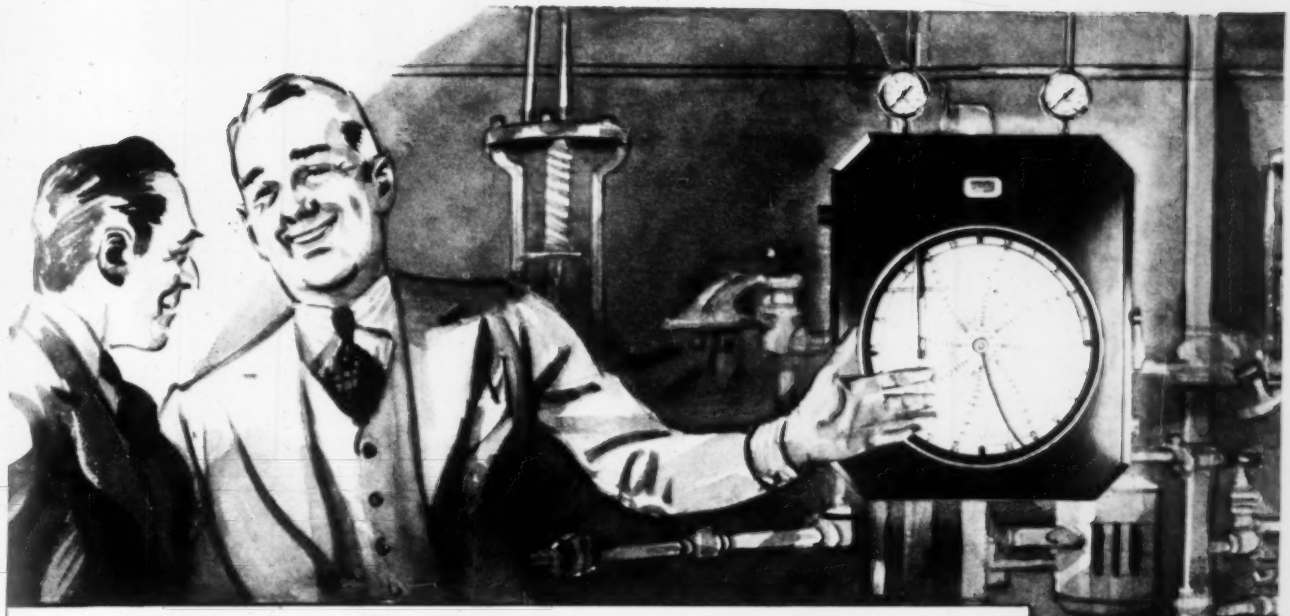
The TAGliabue organization has played an important role in the development of practically every oil testing instrument of consequence, and has been responsible for the introduction and steady improvement of many pieces of equipment now indispensable to the efficient and successful operation of the laboratories of the oil industry.

We invite your inquiry concerning the apparatus shown here, and will be pleased to give you complete information on other TAG Oil Testing Instruments. Ask for your copy of TAG Catalog No. 699D-I.

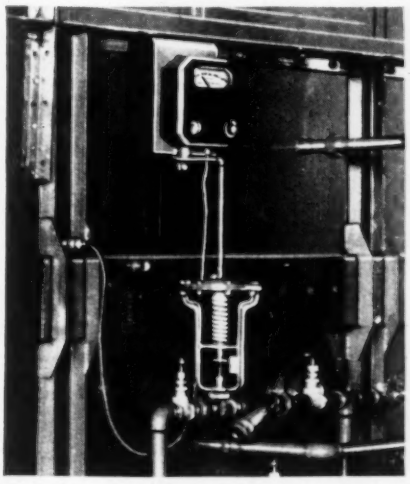
C. J. TAGLIABUE MFG. CO.

Park & Nostrand Ave's., Brooklyn, N. Y.

TAG LIABUE BROOKLYN N.Y. U.S.A.



"...AND HERE'S WHERE WE *Saved $12 a day"*



• Here is a section of a vapor-spray-vapor type degreaser showing Taylor Pressure Control. Taylor Self-Acting Temperature Control, not shown here, is also used. Pressure Control guards against excessive boiling of the solvent and spilling of vapors over the top. *Temperature Control* automatically maintains the correct vapor level with respect to the condensing chamber. It cuts down the supply of steam, keeping the level constant.

An example of how a Fulscope Recording Controller paid for itself... and did a better job of degreasing

THE degreaser in a plating department was eating too much solvent. Consumption amounted to as much as 8 or 10 gallons a day. And the solvent wasn't cheap. It cost about $1.50 per gallon.

So the foreman installed an automatic recorder controller — a Taylor Fulscope. Immediately, the charts revealed large temperature drops.

The operator was cautioned to be more careful. He kept an eye on the chart. And solvent consumption dropped to 2 gallons. Saving: $12 a day.

That's just one example of where Taylor Control on degreasers is paying for itself, and helping to do a better job. You can apply this automatic control to vapor, immersion, and vapor-spray-vapor degreasers. Use it, and see the results in more effective and economical operation.

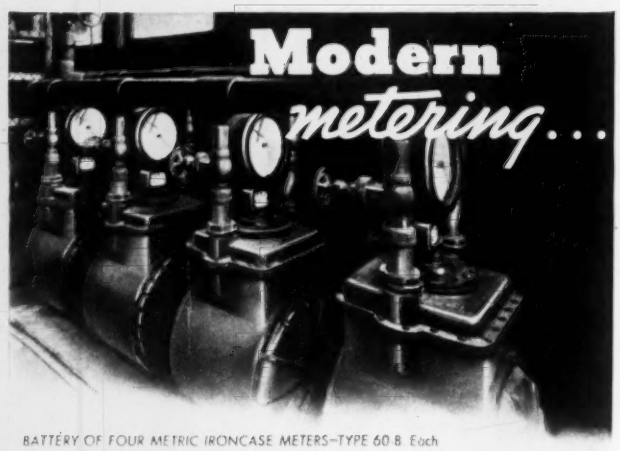
But don't stop with degreasers. Check in your plant the places where temperature, pressure, flow or liquid level regulation is important. Then see if there isn't a Taylor Instrument or System of Control which can quickly increase the efficiency of processing, and decrease costs.

A Taylor representative will put the experience of Taylor Engineering at your disposal, without charge . . . see him — or write direct to Taylor Instrument Companies, Rochester, N.Y.

Taylor

Indicating / Recording • Controlling

TEMPERATURE, PRESSURE, FLOW *and* **LEVEL INSTRUMENTS**



BATTERY OF FOUR METRIC IRONCASE METERS—TYPE 60-B. Each has a capacity of 950 cu. ft. per hour at ½" loss and 2000 cu. ft. at 2" loss, and is equipped with a Westcott Volume and Pressure Gage.

METERS SET UP in parallel, facilitate industrial gas measurement and an uninterrupted chart record of the load. Any meter can be cut out of line, for proving or overhauling. Metric Ironcase Meters—sizes 5-B to 500-B—include types to meet all service requirements. The processed one-piece body resists corrosion and eliminates internal leaks. Friction loss is held to a minimum . . . accuracy maintained at highest standard. Descriptive Catalog EG-40 mailed at your request.

ESTABLISHED 1836
AMERICAN METER COMPANY
INCORPORATED
METRIC METAL WORKS *ERIE, PENNSYLVANIA*

Testing, Research, and Engineering Laboratories require extremely accurate regulation of atmospheric conditions. The slightest fluctuation of temperature or humidity may cause serious variations in the results of important tests.

Because of these rigid requirements for exact and dependable control you will find Powers regulation used in many of the leading laboratories. Being a pneumatic system Powers control can be used in laboratories without danger of ignition of explosive gases. **Write for Bulletin 200.**

47 YEARS OF TEMPERATURE AND HUMIDITY CONTROL

THE POWERS REGULATOR CO.
2734 GREENVIEW AVENUE, CHICAGO, ILLINOIS

OFFICES IN 47 CITIES • SEE YOUR PHONE DIRECTORY

Instruments
THE MAGAZINE OF MEASUREMENT and CONTROL

VOL. 11 No. 12

DECEMBER, 1938

FRONT COVER: Four-zone Control Panel for Largest Heat-treating Furnace in Canada
At Canadian Acme Screw & Gear Co., Toronto
Courtesy The Bristol Co.

EDITORIAL COMMENT 287
Review of National Research Project's Report on Instrumentation

NEW INSTRUMENTS 288
Indicators, Recorders, Controllers, Inspection Devices, etc., for plant, field and laboratory.

BLAST FURNACE INSTRUMENTATION 297
Progress, Present state, Possibilities
By F. N. Hays and J. P. Mikaloff

ROLLING MILL INSTRUMENTATION 301
Including Notes on Heat-treating
By J. L. Whitten

HARDNESS MEASUREMENTS 303
Rebound Methods
By S. R. Williams

MANUFACTURERS' NEW LITERATURE A6

ADVERTISERS' INDEX A6

Published Monthly on the 15th by
THE INSTRUMENTS PUBLISHING COMPANY
1117 Wolfendale Street, Pittsburgh, Pa.

RICHARD RIMBACH, Managing Editor — M. F. BEHAR, Editor

BRANCH OFFICES

Boston: James Condon, 25 Brummer St. (Lafayette 9769)
New York: R. K. Farnham, 118 E. 28th St. (Lexington 2-4637)
Chicago: William Farnham, 201 N. Wells St. (Andover 4180)
Philadelphia: R. K. Farnham, 1533 Cherry St. (Rittenhouse 2530)

Annual Subscription: U. S. $2.00. All other countries $3.00 *payable in advance* (remit by New York draft).

Copyright 1938 by The Instruments Publishing Company.

Entered as second-class matter January 26, 1932, at the post office at Pittsburgh under the Act of March 3, 1879.

Instruments

THE MAGAZINE OF *Measurement and Control*

M. F. BEHAR, Editor

Uncle Sam Discovers Instrumentation

Industrial Instruments and Changing Technology. By GEORGE PERAZICH, HERBERT SCHIMMEL and BENJAMIN ROSENBERG. WPA National Research Project, Philadelphia, 1938. Paper, 7 × 10 inches, xiv + 148 pages. Obtainable (free) from Publications Section, Division of Information, WPA, 1734 New York Ave., Washington, D. C.

ANY reviewer would find that this book reports an extensive study by serious investigators. This reviewer is in position to vouch for the absence of censorship: not only was he the only outside consultant who (to quote the Preface) "reviewed the manuscript" but he tried *and failed* to expunge all "instruments-end-jobs" generalizations.

Now the cat's out of the bag! This review is being written by one who re-wrote some parts of the book under review but couldn't alter other parts. Since it can't be impersonal it will be put in the first person. But first I shall do the *summum jus* by printing the Government's own "review," in full:

WORKS PROGRESS ADMINISTRATION No. 4—1831

For Release to Newspapers,
Saturday P.M. and Sunday, November 26-27, 1938.

Study Finds Increase in Automatic Control in Industry

The widespread introduction of measurement devices and automatic control instruments in industry has speeded up production, improved the quality of products, reduced costs and increased the productivity of labor. This is shown by a report entitled "Industrial Instruments and changing Technology" which was prepared by the National Research Project of the Works Progress Administration and released today by Administrator Harry L. Hopkins.

Although industrial instruments have in some instances served to displace labor, Corrington Gill, Assistant Administrator in charge of WPA research, pointed out in his letter of transmittal that they have also played an important role in the development of such new services or products as air conditioning, radio, plastics, automobiles, and airplanes.

Instruments make for precision control of processes and for efficiency in the use of raw materials, machinery and equipment, the report states. Many modern manufacturing plants employ several hundred instruments in their production processes and some of the larger concerns use thousands. Such industries as petroleum refining and automobile manufacturing, for example, rely heavily on instruments. In the heat-treating of steel, it is pointed out, skilled craftsmen used to judge the temperature of the steel by its color. The introduction of the pyrometer, an instrument which measures and indicates temperature, eliminated the need for this skill but the operation still required manipulation to regulate the temperature. The subsequent development of a temperature controlling apparatus made the heat-treating process almost entirely automatic. The report states that instruments incorporating automatic control features are gradually superseding simple indicating and recording types. Instruments permit economies by the reduction of waste through maintenance of uniform operating conditions and by the use of cheaper raw materials. Inferior materials can be made into products equal in quality to those based on more expensive raw materials.

"Instruments in some instances serve as direct substitutes for labor," the report continues. "Relays, switches and other mechanisms which transfer the actions of an instrument into automatic operations of a machine have eliminated manual workers. Inspection and handling operations are particularly susceptible to automatic control in mass production industries. A wide variety of automatic devices has been applied in these industries to mechanize handling and visual-inspection tasks."

The report also points out that the installation of industrial instruments sometimes results in changes in the specifications for available jobs. "The judgment of a trained workman is frequently made unnecessary by an instrument which indicates a condition so precisely that an unskilled operative can give the process the necessary attention. Where a new skill is introduced it is likely to be of a different sort, for instance, one requiring ability to read meters and perform calculations."

The report is published as a booklet of 148 pages, illustrated, and with numerous charts and tables. It was prepared by George Perazich and associates as one of the reports of the National Research Project on Reemployment Opportunities and Recent Changes in Industrial Techniques directed by David Weintraub.

The foregoing official review rates a cheer for its modest restraint: it isn't a "blurb". Moreover, it mirrors the Report faithfully. The Report *does* contain both kinds of assertions: that instrumentation destroys jobs and that instrumentation makes jobs. The WPA's review does not add, however, what a trained book-reviewer would discover: that the "loss-of-job" allusions are not supported by any figures, case-studies or even hear-say reports.

For that matter, the "job-creation" assertions are not supported as strongly as they could have been. I gave . . . but let that pass! Apart from touches of innuendo* and controversial assertions here and there, the book is purely factual. It really is packed with useful facts.

The information it contains—in text, tables, charts and diagrams—can serve every technician or manager directly or indirectly concerned with measurements and automatic control—can serve, I dare say, everyone in Industry. Most *Instruments* subscribers will find Chapters I (The Rôle of Instruments, 20 pages) and IV (Economic Effects, 27 pages) as well as Appendix A (Principles of Operation, 6 pages) extremely interesting references. Those concerned with the business aspects will find Chapters II and III and Appendices B to G (a total of 63 pages) the proverbial "mine of information." All *Instruments* readers, without exception, will want the book if only for the systematic bibliography which fills its last thirty pages!

The authors, in my opinion, are not biased, not crackpots—just a trio of likeable, reliable young engineers who won't have to use a shoehorn to fit into private industry. Perazich unconsciously gave me a clue when he told me of his education as an Industrial Engineer: what little was taught him about industrial instruments came under the head of "labor-saving." This seems to be done in many engineering schools. It seems also that most fine young graduate engineers now on WPA are convinced that they themselves are victims of "technological unemployment." And yet it is David Weintraub, Director of the WPA National Research Project, who probably has done more than any other man to explode this myth. —MFB

*It's not deliberate innuendo (the authors are as guileless as babes) but it's none the less harmful. To be specific: The Preface states that I "reviewed the manuscript" and "furnished many of the illustrations." This is true. Just under each illustration from a photograph loaned by us there appears the credit word "*Instruments*." This is customary. Under all of these photographs there appear also explanatory captions, some brief, some long. The impression is created that whoever supplied the photographs supplied also these captions or supplied the original captions by which these captions were inspired. This is false. The only manuscript submitted to me was the main text, the "body" of the book. None of these captions was submitted to me. Not a single caption was worded by me. Moreover, the wordings under the photographs on the frontispiece and pages 57, 59 and 79 are so much at variance with the wordings originally printed in *Instruments* that I would have strongly objected to them if they had been submitted to me, because they unduly cry "jobelimination."

THE MONTH'S NEW INSTRUMENTS

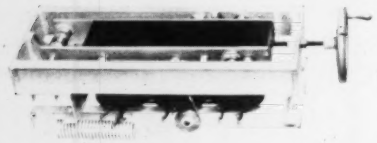
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control—in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Voltage Regulating Reactors

Continuous voltage control for polyphase a.c. power is made possible by new continuously variable polyphase reactor illustrated, which develops a drop



of 300 volts at 50 amps. per coil. By study of mechanical resonance and use of biasing springs, vibration has been reduced so that there is no objectionable noise. Standard parts are available for a number of sizes and maker offers engineering and production facilities in applying this reactor to electrical machinery, furnaces and testing equipment. Assemblies are custom built to meet given voltage and power requirements. *Raytheon Mfg. Co., 124 Willow St., Waltham, Mass.*

High-voltage Resistors

New "Type MV" high-voltage resistors are available in five standard units rated at 5,000 to 100,000 volts; and others for

both experimental and special use, also for surge applications. Resistor with 18½" × 2" tube permits handling 100,000 volts at 150 watts. *International Resistance Co., 401 N. Broad St., Philadelphia, Pa.*

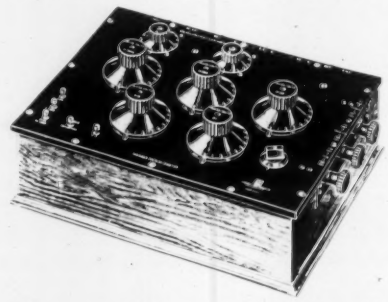
Multi-tester

New Model 109A Universal Multitester (superseding Model 109) has an ohmmeter range to 10 megohms. Ranges include

scale readings 0-100 / 7500 / 75,000 ohms / 7.5/10 megohms. Current range has been extended to 10 amps. D.c. volt readings from 0 to 1000. D.c. microamps. 0-500; milliamps. 0-5 / 50 / 500. Decibel meter readings from −12 to +54 db. Other features are: multiple scales on 5" fan type d'Arsonval instrument accurate to 2%. Sensitivity 2000 ohms per volt. Shunts and multipliers individually calibrated to 2%. *Radio City Products Co., Inc., 88 Park Place, New York City.*

Precision Potentiometer

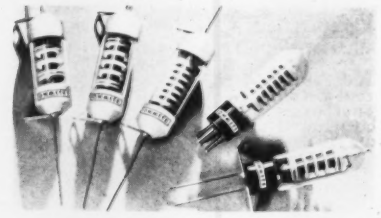
New Wenner Thermocouple Potentiometer permits measurements on its high range (0-0.111110 volt) to be made with in a limit of error of ± (0.01% + 0.5μv.)



and on its low range (0-0.011110 volt) within ± (0.01% + 0.1μv.). Hundredth percent factor can be reduced by applying correction data in NBS certificate supplied with each instrument. Fractional-microvolt factors represent limit of parasitic e.m.f. which no refinement can completely eliminate from a potentiometer of this relatively wide range. Instrument as a whole is "believed to be capable of higher accuracy than any other wide range potentiometer on the market." *Leeds & Northrup Co., 4957 Stenton Ave., Philadelphia, Pa.*

Sealed Resistors

New resistors hermetically sealed in glass provide protection against extreme heat, humidity, salt air, sulphur fumes, etc., in industrial, coastal, marine and



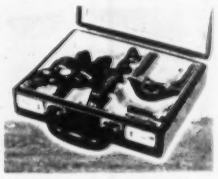
tropical locations. Units are non-inductively pie-wound in 2, 4, 6, or 8 sections, can be repeatedly transferred directly from boiling water to ice water without harm. 1 watt rating; 1% accurate (or closer tolerance when required.) Resistance values from 0.1 ohm to 2 megohms. *Ohmite Mfg. Co., 4835 Flournoy St., Chicago, Ill.*

Solenoid Control Relays

Two new solenoid control relays, [illegible] PB-63 and PB-64 (for moderate [illegible] heavy duty respectively, otherwise [illegible] lar), are designed to provide pump[illegible] control without danger of overheating [illegible] otherwise injuring the solenoid co[illegible] closing rectifier. New feature is that [illegible] noid closing coil circuit is de-energize[illegible] a definite point regardless of con[illegible] switch contacts or other maintained-cl[illegible] contacts. Overheating of solenoid co[illegible] prevented even if closing contacts of co[illegible] trol switch are kept too long in cl[illegible] position. Positive operation is assured, [illegible] is claimed, even for momentary closi[illegible] of the contacts of the control switch. [illegible] lays have a main and an auxiliary el[illegible] ment. Main element is instantaneous [illegible] drop-out, assures operation in case [illegible] control switch makes only momentary contact; auxiliary element consists of [illegible] hinged-armature relay with two pairs of contacts, is energized by a solenoid cut-off switch operated by solenoid mechanism and closing at end of mechanism closing stroke. Its winding may remain continually connected without harm. *General Electric Co., Schenectady, N. Y.*

Oil Field Microscope

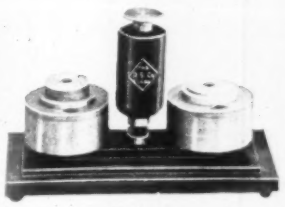
Designed for use by oil scouts, geologists and other field workers requiring a full-size wide-field binocular microscope, "Model RBM-I" outfit features a dust



proof and shock proof case 12" × 10" × 5". Weight complete is 10 lbs. Microscope proper comprises "BI-C" stand, focusing mechanism, "32000" binocular body, pair of "32015" objectives, and pair of "32070" eyepieces. Magnification (regular) is 12×; other eyepieces and objectives available. *E. Leitz, 730 Fifth Ave., New York City.*

Signal Generator

Output of Model 701 direct-reading a.c. all-wave signal generator can be modulated or unmodulated at will. 30% modulation at 400 cycles, sine wave from self-contained independent, 400-cycle circuit. Attenuation inapprox. microvolt calibration by ladder attenuators; range from 1 microvolt to 0.5 volt. Generator continuously variable from 125 kc. to 90 Mc. Five bands on fundamental 90 kc. to 15 Mc. Complete shielding by lead-coated steel chassis and case; separate shielding of coil, attenuator and r-f. circuits. *Radio City Products Co., Inc., 88 Park Place, New York City.*



R. S. DEAD WEIGHT GAUGE

Can be put on a line at any connection where an ordinary gauge is placed. It gives the exact pressure in the line by actual dead weight. The standard gauge is made for pressure intervals of one pound and is supplied with weights and hardwood carrying case in ranges up to 3500 lbs. per sq. in.

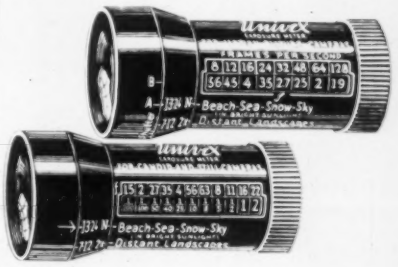
Description and Prices Supplied on Request

THE REFINERY SUPPLY CO.

631 E. 4th St. Tulsa, Oklahoma

Exposure Meters

Two new extinction-method photographic exposure meters are announced: "Cine"



type for m-p. use, "Candid" type for stills. *Universal Camera Corp., 23 W. 53rd St., New York City.*

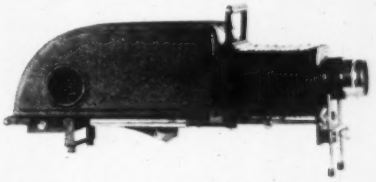
Radio Tester

New "Model 800" combination tube and set tester is said to have been "so designed as to practically set up the serv-

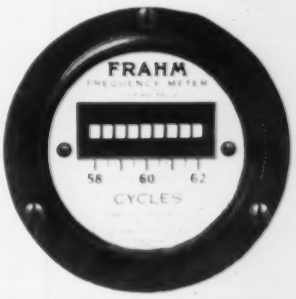
iceman in business." *Radio City Products Co., Inc., 88 Park Place, New York City.*

Slide Projector

New convertible projector for color slides is said to project a 2" × 2" slide with greater brilliance than does usual 1000-watt auditorium lantern-slide pro-



jector with a 3¼" × 4" slide; an iris diaphragm is sometimes needed to diminish screen illumination when using thin slides or projecting to small gatherings. Three models: for 2" × 2" slides only; for 3¼" × 4" slides only; for 2" × 2" and 3¼" × 4" slides. Only difference is in optical units, which can be exchanged in a few seconds. Projector has 750-watt lamp, cooling fan, 3-element condensing system with heat filter and projection lens. Lenses range from 6½" (f2.55) to 10" (f4.23). Weight 21 lbs., dimensions 21" × 7½" × 8¾" high. *Spencer Lens Co., Buffalo, N. Y.*



A DEPENDABLE *MINIATURE* FREQUENCY METER

Just as accurate and reliable as our large, wide-range "Frahm" Frequency Meters. Simple. Rugged. Unaffected by wave form or by ordinary voltage and temperature changes. Available for any frequency between 15 and 500 cycles per sec. Types for front-of-board or flush mounting. Bulletin 1555-I contains complete information.

JAMES G. BIDDLE CO.

ELECTRICAL INSTRUMENTS

1211-13 Arch Street Philadelphia, Pa.

Vacuum . . . Thermocouples

A COMPLETE LINE

embodying many unique features

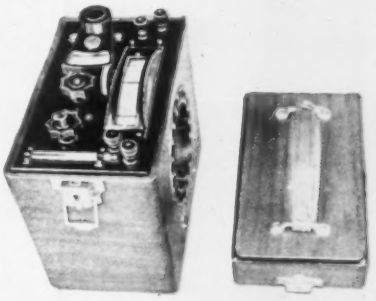
★

- DEPENDABLE STABILITY
- MORE EFFICIENT
- HIGHER OVERLOAD
- FASTER RESPONSE
- SMALLER SIZE—½"x1"
- LOWER COST

These thermocouples will meet the most rigid specifications. Prompt delivery is assured. Write your requirements to:

AMERICAN Electrical Sales Co., Inc.

67 E. 8th St. New York, N. Y.



"Sales Mean Jobs"

WHEELCO Portable Potentiometer

with removable cover

- Instrument accuracy, ¼ of 1%.
- Scale length, 42".
- Thermometer attached for cold junction corrections.
- Ruggedly constructed to overcome abuse.
- Completely self-contained with run-up box.
- Supplied with Millivolt, Centigrade or Fahrenheit Scales.
- Compact walnut case with removable cover.
- Uses any thermocouple.

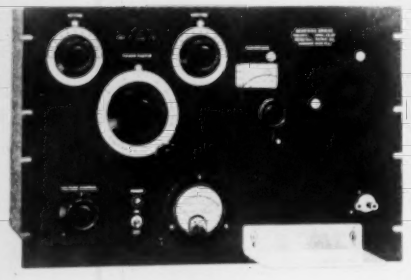
Detailed information on request

Wheelco Instruments Co.

1933 So. Halsted St. Chicago, Ill.

Schering Bridge

New "Type 674-A" Schering Bridge has been designed for measurements of dielectric properties of insulating material at power line frequencies; testing of materials used as dielectrics in capacitors and as insulation in transformers, cables and electrical machinery, also for tests on ceramic, fabric, paper and plastic products, to determine such properties



as composition and moisture content, as well as change in these characteristics with temperature, humidity and voltage gradient. A substitution method of measurement is used. Capacitances up to 1000 $\mu\mu f$ can be measured with an accuracy of ± 1 $\mu\mu f$. For small samples, power factors up to 80% can be measured. Voltage applied to sample under test can be varied between 0 and 1100 volts. Input power is 30 watts from 60-cycle line. Bridge is designed for mounting on a standard 19" relay rack. *General Radio Co., 30 State St., Cambridge, Mass.*

Capacitance Test Bridge

Both the accuracy and the speed of routine measurements are said to be greatly improved by new "Type 740-B" capacitance test bridge for measuring

capacitance and power factor of paper, mica and electrolytic capacitors; measuring inter-conductor capacitance in cables and interwinding capacitance in transformers as well as production testing. Bridge is direct reading in capacitance and power factor. Power is obtained from a 115-volt 60-cycle a.c. line. Power input is 15 watts. A visual null indicator is included, and no accessories are necessary. Instrument is supplied in an airplane luggage type of case with carrying handle; weighs 19 lbs. Range of capacitance measurement is 5 $\mu\mu f$ to 1100 μf. Accuracy over most of this range is $\pm 1\%$. Power factor range is 0 to 50%. *General Radio Co., 30 State St., Cambridge, Mass.*

Without opening circuit to insert an ammeter you can measure alternating current by using a **RUBICON**

SPLIT CORE TEST SET

Highly useful in checking motors and other devices for load, performance and phase balance without interfering with operation. Simple, accurate and inexpensive. Ranges to 1000 amps.

Send for Bulletin No. 180

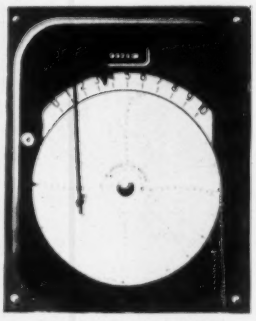
RUBICON COMPANY

Electrical Instrument Makers

29 North Sixth St. Philadelphia, Pa.

ACCURATE CONTROL

Distinguished for extreme accuracy and high quality, Cochrane flow Meters are reliable guides for compiling records of consumption, intake, output and variation in the rate of flow of steam, gases, water and other liquids. The Electric Model utilizes the galvanometer null principle.



ELECTRICAL MODEL

MECHANICAL MODEL

The sensitive galvanometer detects the slightest change in rate of fluid flow, unaffected by friction or variations in voltage or frequency. Can be installed any distance from pipe line. The mechanical model develops an extremely high torque, is accurate in design, simple and rugged in construction.

ORIFICE METERS AND TYPE E WEIR METERS

—have the same Cochrane accuracy and simplicity and are highly regarded by users for their particular applications.

Write for Publication Nos. 2092, 2094, 2096

COCHRANE CORPORATION

3120 N. 17th Street Philadelphia, Pa.

COCHRANE

FLOW METERS

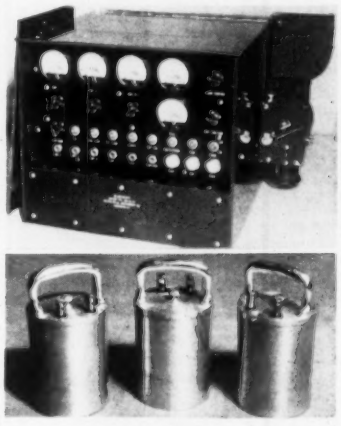
Electric-contact Ty[illegible] Controllers

"Hydraulic Action" line of anti[illegible] controllers for warm air, hot-water [illegible] fans, etc., is thus designated by [illegible] of liquid-filled measuring-and-ope[illegible]

tube systems, "sealed permanently both in respect to sensitive element and switch" and exerting "practically unlimited power." Illustration shows a dual-system model: fan or warm air limit switch "Type LF/19." *Julien P. Friez & Sons, Baltimore & Central Aves., Baltimore, Md.*

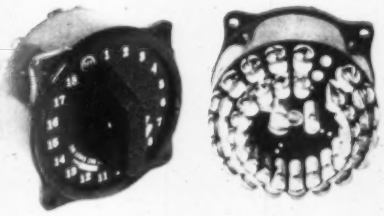
Seismic Prospecting Apparatus

Geophysical prospecting apparatus employs refraction seismic technique, can be transported by truck, pack animal or by men traveling on foot. Heaviest unit,



oscillograph, weighs 50 lbs. Outfit comprises: (1) Three-element oscillograph which embodies also calibrated tuning fork time-line recorder; (2) Daylight loading camera taking standard film and provided with speed governor, numbering wheels, automatic centrifugal switch for firing shot when film speed has attained desired constant value, removable film container, film cutter, etc.; (3) Five carbon-microphone type detectors; (4) Full set of auxiliary equipment for photography, shot-hole boring, etc. *Geophysical Instrument Co., 1515 Half St., S. E., Washington, D. C.*

ROTARY SELECTOR SWITCHES *for use with* THERMOCOUPLES



There is a "LEWIS ENGINEERED SWITCH" suitable for every multiple thermocouple installation.

Every Switch has an "OFF" position. Every model is designed exclusively for the small voltages generated by thermocouples. Low contact resistance permits very accurate readings.

STANDARD STOCK MODELS

Part No.	No. of Pos. besides "Off" Pos.	Nominal O.D.	Approx. Wt.
11S	2, 3, 4	2.5"	7 oz.
10S	6, 9, 12, 18	3.0"	19 oz.
12S	24, 28	4.0"	25 oz.

DELIVERIES WITHIN 48 HOURS FROM RECEIPT OF ORDER

Bulletin 8-7 On Request

THE LEWIS ENGINEERING CO.
NAUGATUCK, CONNECTICUT

FOR ACCURATE GAS ANALYSIS . . .

HAYS Portable Combustion Test Sets are in high favor with traveling engineers. The one shown above includes a 3-unit gas analyzer (CO_2, O_2 and CO), a metal armored flue gas thermometer and a Dry Type Draft Gage. Each unit may be used independently of the others. The Hays is known as the "world's fastest Orsat" —complete analysis within 3 to 4 minutes. Extremely accurate, sturdy in construction, compact in size. Many other types available. Send for Catalog 38-323. Write Dept. 11-12-8.

The HAYS CORPORATION
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

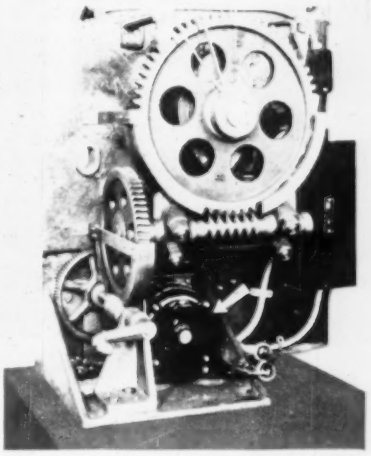
Nine-inch Line of Industrial Instruments

To maker's line of recorders, recorder-controllers and indicating controllers in 12" and 10" sizes is now added a corresponding series of 9" instruments. Black enamel and chromium cases, though

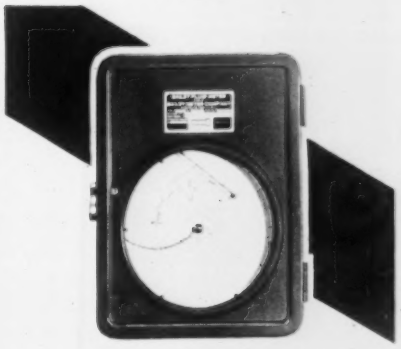
smaller, contain all features of larger series (*Instruments*, May 1933, page 109; Jan. 1934, page 14; Oct. 1938, page 263; Nov. 1938, page 275). *C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

Flow-rate Controller

For maintaining constant flow-rate in a pipe-line despite variations in head of supply source, new automatic control system consists essentially of a flowmeter,



control switch, "Ohio Torque Motor" and butterfly valve. When pipe-line head varies, torque motor is energized and through gearing alters opening of butterfly valve which is located downstream of Venturi tube. For practical reasons it is said not to be feasible to cause valve to open in one direction only, and it therefore is allowed to "open a little too much and then to close a trifle until opening is correct." Ohio torque motors have been selected for this work, it is said, because they can exert full load torque with only full load current even when stationary, and can be repeatedly stalled on full voltage without injury. *Simplex Valve & Meter Co., 7555 Upland St., Philadelphia, Pa.*



BAILEY *Fluid Meters*

For STEAM · LIQUIDS · GASES

● Bailey Fluid Meters are designed to indicate, record and integrate the flow of steam, liquids, or gases under practically any pressure or temperature condition.

A great variety of indicating, recording and integrating combinations are available for use with four distinct types of flow mechanisms.

This large variety of possible combinations enables the flow meter engineer to specify equipment which is pre-eminently suited to any flow measuring application.

When it is desired to place indicators, recorders and integrators at a considerable distance from the primary element, Bailey Synchro-Meters are available to provide electric transmission.

For detailed information consult Sweet's Engineering Catalogs or request a copy of bulletin No. 301.

BAILEY METER COMPANY
1041 IVANHOE ROAD · CLEVELAND, O.
Bailey Meter Company Ltd., Montreal, Canada

A big help in any electrical control problem

Write for new catalog it's free!

STRUTHERS DUNN, INC.
125 N. Juniper St.
Philadelphia, Pa.

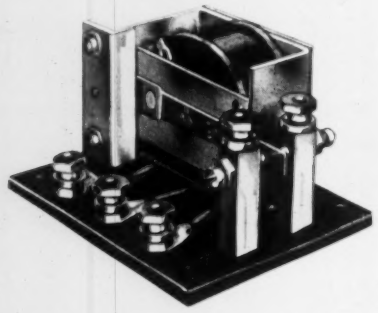
Foot-candle Meter

Five models of new "Photomet" foot-candle meter are announced: "Model 2584," sensitivity 0.05 ft-c., range up to 250 ft-c.; "2583" with visual correction

filter, sensitivity 0.1 ft-c., range up to 500 ft-c.; "2584-B," sensitivity 0.01 ft-c., range up to 50 ft-c.; "2584-C," sensitivity 0.005 ft-c., range up to 25 ft-c. For use in photographic work an exposure calculator and an enlargement calculator are available. Case measures $9\frac{1}{4}$" × $13\frac{1}{4}$" × $5\frac{1}{8}$" high. Photocell is new "Visitron" (see *Instruments*, Oct. 1938, page 256), is attached to a special G-M microammeter by a flexible 8-ft. cable. No batteries are required. Scale has 50 divisions, is numbered with four different ranges. Unit needs no special leveling and has a knife-edge pointer to allow close reading. *G-M Laboratories, Inc., 1731 Belmont Ave., Chicago, Ill.*

Relays

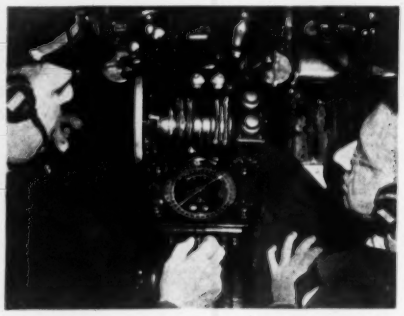
Numerous additions are announced to maker's line of relays and general circuit controls. Illustrated is "Electronic Relay Type 850," for us in electron-tube circuits. Coil resistances up to 30000 ohms are available, at which point this relay operates on 11 milliwatts (and through sensitive adjustments on 4 milliwatts).



Screw-type sensitivity adjustment changes air gap between armature and pole face so that, if desired, relay will fall off contact at 30% less voltage than that required to make contact. Contact combination is s.p.d.t. single break, with pure silver contacts rated at 1.5 amps. 110 volts. Mounted on 3-16" Bakelite base; over-all dimensions $2\frac{7}{8}$" × $2\frac{1}{4}$", height 2". *Advance Electric Co., 1260 W. 2nd St., Los Angeles, Calif.*

Aircraft Automatic Direction Indicator

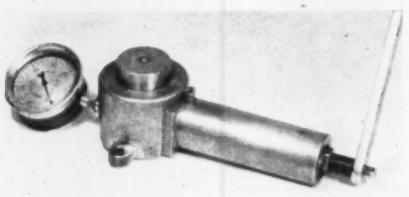
When once tuned to a station, Sperry-RCA Automatic Direction Finder points to it continuously and automatically, continues to give bearing even up to the point of passing over station, immediately shows pilot when he has passed over sta-



tion and gives positive information to confirm "cone of silence" which he may have received if he has been flying on regular radio beam. Device provides also a radio means of obtaining drift or "crab" angle that plane must take to make allowance for wind. When flying along one of regular beams, any station to right or left of course may be tuned in and pointer will indicate how far along beam the plane has progressed. Automatic feature permits obtaining bearings when static prevents obtaining a null or "no signal" if operating ordinary type of hand-operated loop. Design features: face of instrument is mounted horizontally so that azimuth readings are shown in the plane in which they are actually measured and pilot orients himself by identifying direction of station with direction of arrow head relative to miniature airplane shown on face of instrument. Navigation scales eliminate arithmetic. All dials and switches are within easy reach but spaced to avoid confusion in darkened cockpit. *Sperry Gyroscope Co., Inc., Manhattan Bridge Plaza, Brooklyn, N. Y.*

Hydraulic Test Jack

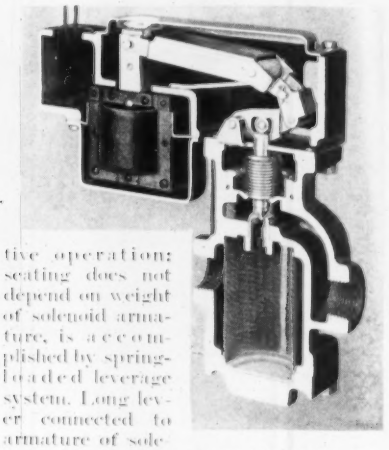
"No. 28" hydraulic screw piston jack has been designed for determining unknown power pressures between fixed bodies or mechanical power resultant as in a screw or crank thrust, in laboratory



and maintenance work. It comprises an integral hydraulic lift cylinder and ratchet-screw power piston having a knurled faced ram end. All parts are hardened steel, ground and polished on the surfaces in contact with the oil pressure medium. Unit is available in 25-ton and 50-ton capacity with gage readings in ton unit pressure graduations. *Dorr-Patterson Engineering Co., 3052 Wight St., Detroit, Mich.*

Electric Valve

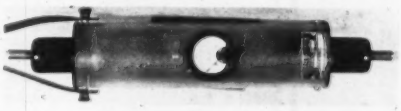
Departing from conventional [illegible] new electrically operated valve [illegible] veloped to insure tight closure against pressure up to 150 lbs. and assure [illegible]



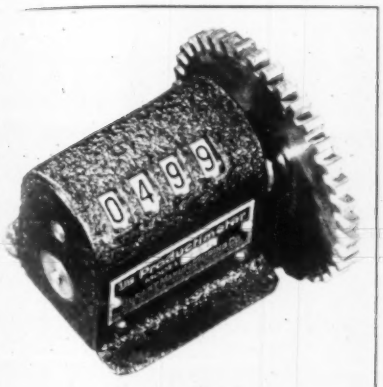
tive operation: seating does not depend on weight of solenoid armature, is accomplished by spring-loaded leverage system. Long lever connected to armature of solenoid gives sufficient mechanical advantage for positive opening. Valve and seat are stainless steel of file hardness. Packing is eliminated by use of Sylphon bellows. Slot-and-roller construction, obviating all angular stress on valve stem, assures straight thrust of cone when seating. Button at end of long lever provides for manual operation or testing. Discharge capacity from 1100 to 3300 lbs./hr. (of water) depending on differential between inlet and discharge pressures. Standard electrical rating 115-V, 60-cycle, but coils for other voltages and frequencies are available. *McDonnell & Miller, Wrigley Bldg., Chicago, Ill.*

Phasing-out Voltmeter

Designed for use in phasing out power-distribution circuits, new unit consists of an instrument connected in series with a small neon lamp and two high-voltage



resistors, mounted on a strip of high-dielectric-strength and leakage-resistant insulating material, all housed in a transparent plastics tube etched outside except for a window. Instrument is a rectifier-type milliammeter. Shunted around it is a suitable resistor, so that should circuit open in instrument, voltage would cause neon lamp to continue glowing. Because of this arrangement, all voltage is applied to neon lamp until it starts to glow. This permits checking operation of both lamp and instrument on voltages as low as 110. Safety features: (1) approximate value of impressed voltage is indicated by instrument; (2) lamp glows at all voltages above 110; (3) every voltmeter is given a 15,000-volt test between circuit and external exposed parts. Weight (4½ lbs.) and dimensions (20" × 4½") of voltmeter make it suitable for use by construction crews and linemen. Indicator scale range is 0-5000 volts but 10,000 volts may be applied momentarily. *General Electric Co., Schenectady, N. Y.*



100 Standard Models of Registering Instruments

Among Durant *Productimeters* for registering strokes, revolutions, or lineal measure can be found the right instrument for almost any requirement in counting or measuring.

Ask our field or factory engineers for recommendations on any new or special counting problems you may have.

Productimeters
THE SPEEDOMETERS OF INDUSTRY

DURANT MFG. CO.
1930 N. Buffum St., Milwaukee, Wis.
182 Eddy Street, Providence, R. I.
Sales Offices in all principal cities

TELL US WHAT YOU WANT TO COUNT

Portable Potentiometer

New current standardizing device makes it possible to use this potentiom-

Fig. 1

eter in aircraft and other applications where severe vibrations are met. Device, called "Thermo-Cell," is heater and thermocouple in vacuum, having inflected curve relation of heater current to thermocouple e.m.f. shown in Fig. 1. It is connected in series with slide-wire as

Fig. 2

shown in Fig. 2. V-t. thermocouple *T* is connected to a d.p.d.t. switch for transferring galvanometer from *T* to measuring thermocouple. Galvanometer is double-pivot, cobalt-magnet type, said to give greater unit deflection than most suspension types and so damped that slide-wire current can be checked in a few seconds. *The Leeds Engineering Co., Naugatuck, Conn.*

Accurate Temperature Control

Temperature control "on the straight and narrow" is the result produced by the Capacitrol. A "mere mg" movement of the indicator is sufficient to insure instantaneous control action without direct contact with any control mechanism. All electronic in operation and entirely devoid of mechanical parts, such as timing motors, decession bars, gears and cams, the Capacitrol provides precision control at low first cost and NEGLIGIBLE maintenance costs.

WHEELCO INSTRUMENTS CO.
1933 SO. HALSTED STREET, CHICAGO, ILL.

GALLET · GUINAND · GALCO and SECURITY TIMERS

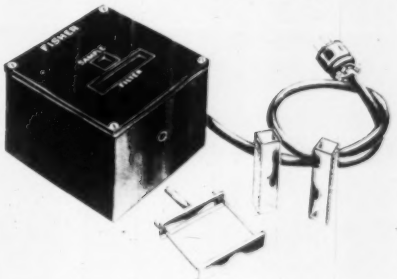
are made by the world's best chronograph craftsmen

FREE CATALOG ON REQUEST

JULES RACINE & CO.
20 WEST 47th STREET • NEW YORK

Micro Attachment for Electrophotometer

Adapting Fisher Electrophotometer to conduct colorimetric analyses with samples as small as 1 ml., new micro attachment is a photocell unit including lamp, cell holder, 1 ml. fluid cell, filter holder



and photocell, in a box 4½" square and 4" deep with openings at top to allow insertion of fluid cell and filter holder. Cell is 13 mm. square; filter holder will accommodate the standard 2" square Corning Filters now furnished as accessories to the Electrophotometer. *Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.*

TEST MAGNETIC PROPERTIES OF YOUR STEELS

RAWSON FLUXMETER
SIMPLEST AND MOST EFFICIENT
Bulletin 504

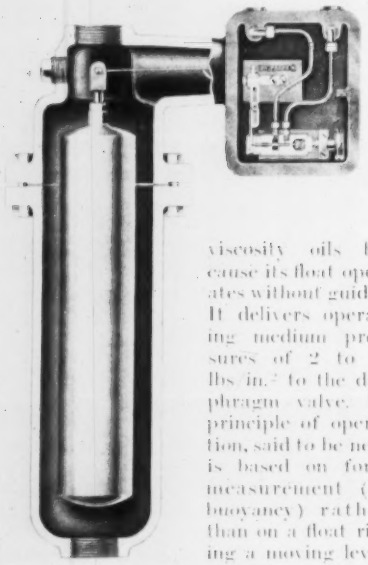
Dynamometers, wattmeters, milliammeters and voltmeters. Also ultra-sensitive meters both for A.C. & D.C., fluxmeters, electrostatic voltmeters from full scale 120 volts to over 20,000 volts, thermocouples, earth current meters, cable testers, etc.

Acknowledged leaders in development of high sensitivity meters

Rawson Electrical Instrument Company
110 POTTER ST. CAMBRIDGE, MASS.
Branch: 15 East 26th Street, New York City
Representative: E. N. Webber
1313 W. Randolph St., Chicago, Ill.

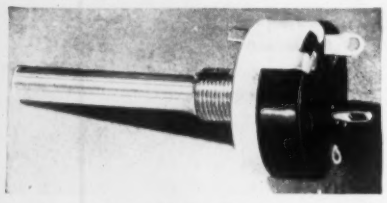
Liquid-Level Controller

New "Type 246 Level-Trol" is a remote type, throttling mode, pneumatically operated controller for liquids of all gravities, but especially suited for high viscosity oils because its float operates without guides. It delivers operating medium pressures of 2 to 15 lbs./in.² to the diaphragm valve. Its principle of operation, said to be new, is based on force measurement (of buoyancy) rather than on a float riding a moving level. All lost motion is said to be eliminated from the float mechanism. Maker states that a ⅛" level change will register a pressure change at the diaphragm. "Level-Trol" is available in two sizes: 14" and 32" adjustable level changes (total ranges). *Fisher Governor Co., Marshalltown, Iowa.*



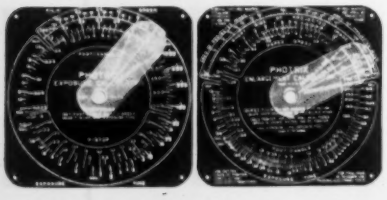
Rotary Switch

New fully enclosed rotary type power switch operates on an arc of 30°. Dimensions: 1 3/32" dia., 9/16" deep; various bushing and shaft lengths. Available in s.p.s.t., d.p.s.t., s.p.d.t., s.p. with bushing terminal, s.p. reverse operation, and 4-wire s.t. *Clarostat Mfg. Co., Inc., 285-7 N. 6th St., Brooklyn, N. Y.*



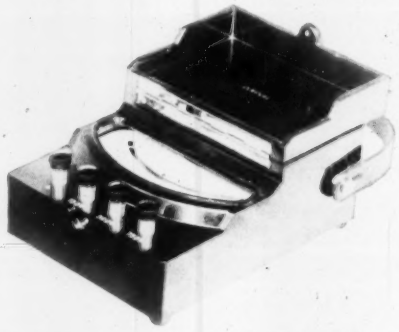
Photrix Calculators

Two calculators have been added to Photrix line. (1) Photrix Exposure Calculator converts any light measuring device into an exposure meter, is meant in particular for light meters of high sensitivity which photographer must use where pocket-type exposure meters fail to indicate; its scale goes down to 0.025 foot-candle. (2) Enlargement Calculator is designed to find required enlarging time after light emerging from lens of enlarger has been measured with Photrix Photometer or other light meter suited for purpose. This calculator in combination with the photometer is said to represent the first method on American market for determining required enlarging time photoelectrically, without aid of visual comparison. Both calculators are of etched aluminum, turnable disk 3" diam., base plate 4" × 4". *Intercontinental Marketing Corp., 8 W. 40th St., New York City.*



Medium-size Portable D-c. Instruments

New "Type DP-9" instruments have concentric-magnet elements: two sector-shaped Alnico magnets ground to dimensions and placed inside a soft steel ring, and assembly die-cast together. With core and armature assembly supported in a separate die-casting, design is essentially a two-unit construction with a directly removable core assembly and moving system. Uniform scale distribution is maintained by bonding a thin shell of cold-rolled steel to individually magnets along inner periphery. High air-gap flux density assures high torque in all ratings, including microammeters. Self-shielded magnetic circuit is said to make new instrument "fully the equivalent of a laboratory secondary standard in this respect." Dimensions 2 7/16" × 6-9/16" × 4-13/16"; weight 3 lbs. Mirror scale 4.1" long. Standard accuracy 0.5% of full-scale value. *General Electric Co., Schenectady, N. Y.*



Voltage Regulator

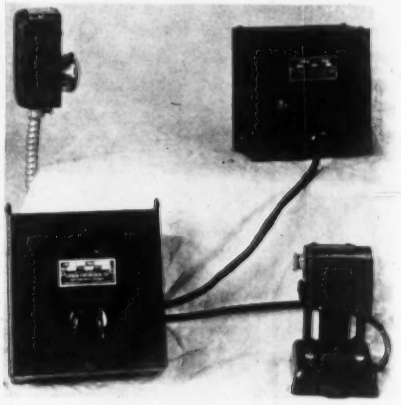
New panel type "Voltrol" is designed to fit as an integral part of electrical testing apparatus, is more compact than older models, is said to permit stepless adjustment of a.c. voltage from 0 to 135 volts. Basically consists of a specially-designed heavy duty auto-transformer. Makers state that operating characteristics tests established accuracy of instrument to adjustments within 0.4 volt. *Acme Electric & Mfg. Co., Cuba, N. Y.*

Signal Generator

New "Model 571" signal generator has range of 65 kc. to 20.5 Mc. on fundamentals and unlimited on harmonics. Five fundamental bands read on two basic scales. Other features: Hairline shadow indicator eliminating parallax; illuminated dial opening; variable iron core coils thoroughly impregnated; two-speed dial drive; two levels of audio modulation, 30% and 75%; double shielded throughout; 20 volt line supply variation results in r-f. change in cycles; c.w. C.W. or 400-cycle audio modulated r-f. wave available; can be used as standard 100-kc. or 1000 kc. signal source for harmonics. *Supreme Instruments Co., Greenwood, Miss.*

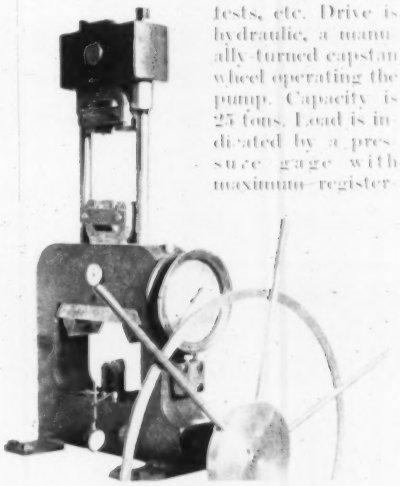
High-speed Counter

New "Type PC-3 Counting Unit" is supplied complete with photoelectric cell relay, light source, power supply and counter. Polarized plug connections for cables increase equipment's usefulness on multiple installations by permitting photocell amplifier and relay to be removed for check or replaced in several seconds. Accuracy guarantee is 600 counts per minute. Estimated tube life, 7,000 to 10,000 hours. *Lipman Engineering Co., 415 Vau Braam St., Pittsburgh, Pa.*

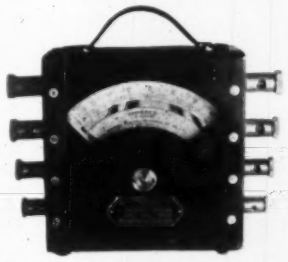


Abrasive Products Testing Machine

Though designed for use in abrasive field, this bench-mounting tester is suited for other materials as well. Upper part has jaws for tensile tests; lower part has anvils for bending tests, etc. Drive is hydraulic, a manually-turned capstan wheel operating the pump. Capacity is 25 tons. Load is indicated by a pressure gage with maximum-register ing hand. Elongations and deflections are indicated by micrometric dial gages. *Dorr-Patterson Engineering Co., 5462 Wight St., Detroit, Mich.*



KNOPP
Multirange A. C. Ammeter

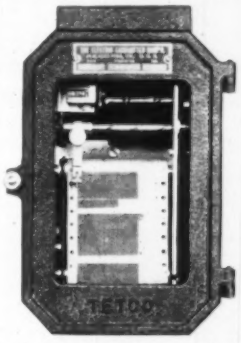


Entirely Self Contained—Meets Maximum Test Requirements

7 Ranges 2 to 200 Amperes
Weighs 5½ Pounds 5½" Scale
Accuracy Within 0.7%

Western Electro-Mechanical Co.
INCORPORATED
OAKLAND, CALIFORNIA

TETCO
Speed Recorder



Creates a permanent time record on a waxed chart. Accurately records rate of production, time and duration of stops, total quantity produced.

The Electric Tachometer Corp.
1358 Spring Garden St., Philadelphia, Pa.

OPTICAL UNITS
for instruments

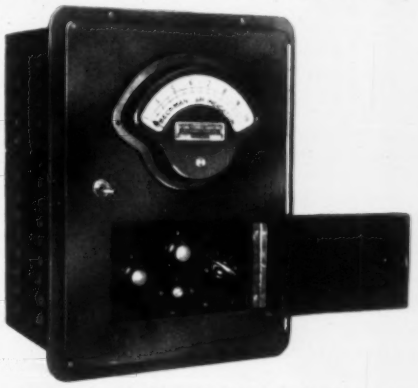
•

Optics in both Natural and Fused Quartz . . . Plano Parallels to Any Degree of Accuracy . . . Prisms of All Types . . . Galvanometer Mirrors . . . Metal Mirrors of Any Precision

Master Optical Company
Precision Lenses and Prisms
19 W. 36th St. New York, N. Y.

Automatic pH Instrument

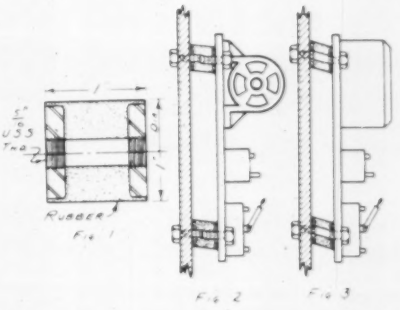
Developed for sugar, paper, leather and other industries requiring large-scale pH control, new type of pH instrument incorporates a potentiometric circuit au-



tomatically balanced by a 110-volt a.c. operated electronic amplifier. Fluctuations in supply line voltage are automatically compensated. Device uses Beckman Glass Electrodes (see *Instruments*, April 1938, page 110) whereby continuous control can be maintained over flowing solutions without need of sampling devices. Provisions are made for connecting additional indicators at any distance and for connecting a controller mechanism and any standard recording potentiometer, without special calibration or special accessories. By means of a resistance thermometer incorporated in electrode assembly, a temperature compensator automatically adjusts instrument to changes in temperature of test solution. Unit is available in standard scale ranges of 0-7 pH, 3-10 pH, or 6-13 pH in 0.1 divisions (others on special order). *National Technical Laboratories, 3070 E. Colorado St., Pasadena, Calif.*

Rubber Mounting

Deflection of new "Type 40 Vibro-Insulator" can be regulated by user to provide either a soft or stiff type rubber mounting, as desired. This is made possible



through construction shown in Fig. 1: rubber vulcanized to two parallel metal disks drilled and tapped for a 5/16 U.S.S. thread; and deflection varied by length of attaching screws. Fig. 2 shows relatively stiff, small-deflection mountings; Fig. 3 shows how full cushioning value is utilized by attaching with short screws. Type 40 Vibro-Insulator is offered in only 1" x 1" size; maximum load in shear, 10 lbs. per mounting. *Mechanical Rubber Goods Div., The B. F. Goodrich Co., Akron, Ohio.*

ELECTROCELL

Self-Generating
Photo-Electric Elements
Ultra Sensitive
Permanently Stable
Unlimited Life

Great variety of sizes and shapes
Round cells from 3/8 to 2 3/8 Dia.
Mounted or unmounted

NEW: • • •
Foot Candle Meters of unequalled sensitivity up to 1 1000 ft.-cdl.

PHOTRIX
UNIVERSAL PHOTOMETER
Single and multiple cell models

PRICES From
$37.50 Up

DR. F. LOEWENBERG
10 East 40th St. New York, N. Y.

The All Purpose
AIR VELOCITY METER

"Alnor" Velometer

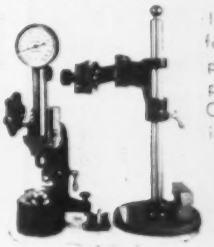
Instantaneous
Direct
Reading

No Timing
No Calculations
Write
for Literature

ILLINOIS TESTING LABORATORIES, Inc.
142 W. Austin Ave. Chicago, Illinois

HARDNESS TESTING...

done WITH NO MENTAL HAZARDS. The SCLEROSCOPE has done it for the past 30 years.



In general use for specification purposes. Simple, sturdy. Comparatively inexpensive.

Illustrated bulletins free.

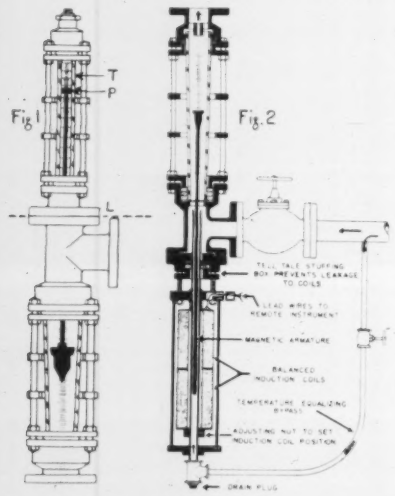
The Shore Instrument & Mfg. Co., Inc.
9025 Van Wyck Avenue, Jamaica, N. Y.

New Rotameter Types

Brief abstracts for six descriptions communicated to *Instruments* simultaneously: (1) *Rotameters with Heating or Cooling Jackets.* For liquids which would freeze at room temperature, and for other liquids which would flash into vapor at room temperature. End fittings are jacketed for circulating heating or refrigerating medium; metering tube itself is surrounded by clear glass tube and intervening space evacuated to approx. 1μ Hg.

(2) *Rotameters for Opaque Liquids.* Consist of standard Rotameter (below line *L*, Fig. 1) with its float connected to piston *P* which is visible because it closely fits precision-bore glass tube *T*. Holes in piston prevent dash-pot effect.

(3) *New Designs of Electric Telemetering Accessories.* In small sizes, transmitter coils are now arranged in a cylinder mounted directly around a standard Rotameter, preventing leakage, light



ening assembly of float and extension rod and permitting more accurate transmission of low-flow readings. In large sizes, telemetering components have been completely re-designed (see Fig. 3).

(4) *Automatic-control Instruments.* New ones consist of Cochrane induction-balance type recorder, with Taylor "Fulscope" pneumatic-relay control block.

(5) *"Universal" Models.* End fittings of model described in March 1938 *Instruments*, page 81, simplified; over-all lengths shortened; appearance of new design suits modern panel-boards.

(6) *Standardized Floats.* In 10% increments so that, for any desired maximum capacity between 0.1 and 100 g.p.m. liquid, a float picked from stock can be shipped to user with assurance that less than 10% of upper end of scale will be wasted. *Fisher & Porter Co., 114 W. Penn St., Germantown, Philadelphia, Pa.*

pH Test Papers

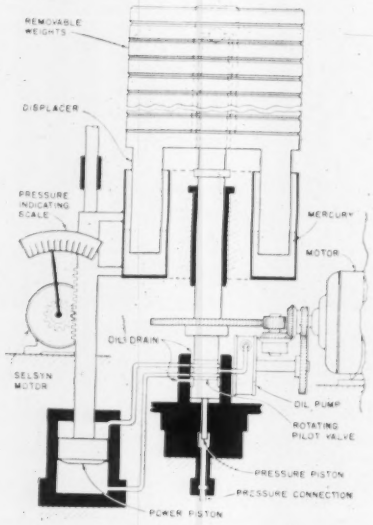
Used like ordinary litmus paper but capable of approximate measurement. "Alkacid" test paper gives five color changes:

pH	2	4	6	8	10
Color	red	orange	yellow	green	blue

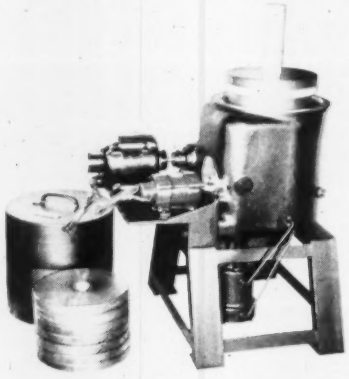
Is supplied in vials of 100 strips, with color charts. *Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.*

Dead-weight Pressure Telemetering System

Employing null-method self-balancing whereby 0.1% accuracy can be guaranteed, and dead-weight "piston" design whereby 12,000 lbs. in.^{2} can be measured,



new "Power Type Pressure Gage" serves also as the transmitter of a position-motor type telemetering system. Basic principle (Fig. 1) is identical with that used in maker's Power Type Pressure Device (*Instruments*, May 1931, pages



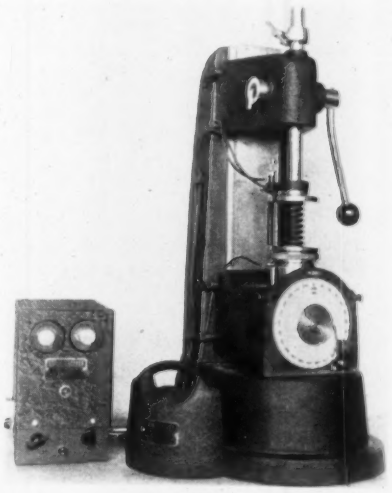
288-289; Jan. 1938, page 10) except that in new design it is the power piston which supports the mercury container, so that amount of suppression in suppressed-zero ranges can be altered in a few seconds. For example, a 2000-lb. range transmitter (Fig. 2) can be used for 5000-7000, then for 60000-80000, etc. *Bailey Meter Co., 1071 Ivanhoe Rd., Cleveland, Ohio.*

pH Test Papers

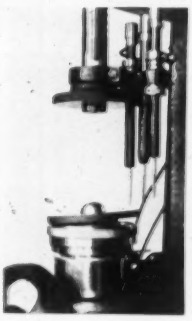
Used like ordinary litmus paper but capable of approximate quantitative measurement, new series of "Hydrion Wide Range" test papers gives readings to within 0.5 pH unit over full range of 1 to 11, by means of a chart printed in 11 colors. There are also announced (1) a set of 11 buffer solutions; (2) a translucent plastic comparison plate. *R. P. Cargille, 118 Liberty St., New York City.*

Spring Checker

New "Model PBL-250 SUL" is a lb. capacity, graduated in pounds, dicates simultaneously by the acti neon lamps: (1) if a spring when



pressed to specified height comes within stated load tolerance, and (2) if, under its rated load, it shows a squareness of end with its axis, within specified angle limit. First check is accomplished by a current passing through a stylus, pre-set for specified compressed height, and a finger bearing on a load contact dial, set to load tolerance specifications, and rotating with load dial. (For some conditions a double-stylus arrangement is used in lieu of load contact dial.) This circuit indicates by flashing left-hand neon lamp on control board. Check for squareness under-load is made simultaneously by means of a duplicate circuit, which indicates result on right-hand neon lamp: On weighing-table and insulated therefrom, is a tilting-plate (see Fig. 2) on a ball-bearing ball-and-socket mount, over a contact-making micrometer sleeve graduated in 5' of arc divisions. Electric circuit for each indicator is "an electronic circuit of the trigger type" and current flow is too small to burn contacts. *Link Engineering & Mfg. Co., 1074 W. Baltimore Ave., Detroit, Mich.*



pH Test Papers

New "pH Papers" are strips impregnated with sensitized indicator and a number of "control bars" representing pH values. For general application, "Universal" series of five indicators gives readings from 2.0 to 12.0 pH; "Series A" (six papers) covers pH range 2.6 to 9.7 in steps of 0.2 or 0.3; "Series B" (four papers) give readings within 0.2 over pH range 3.9 to 8.9. Numerous others include series reading to 0.1 pH and series for sugar, dairy, electroplating, etc.—*Paul Frank, 556 Fourth Ave., New York City.*

Blast Furnace Instrumentation

Presented at the Conference on Instrumentation in the Steel Industry, Carnegie Institute of Technology, Oct. 14, 1938

By F. N. HAYS and J. P. MIKALOFF

Carnegie-Illinois Steel Corp., Duquesne, Pa.

BLAST FURNACE operators adopted instruments for operating guidance long before their value was recognized by other producing departments in the iron and steel industry. Since then, great progress in development and application of blast furnace instruments has been made possible by the coöperation, encouragement, and initiative of the furnacemen, as well as the collaboration of plant engineers and instrument manufacturers.

For the past ten years instrumentation at blast furnaces has lagged in comparison with the rapid advance in other steel mill departments, but it is believed that the need has become apparent and that the traffic light has turned green to both furnacemen and instrument manufacturers for the following reasons:

(1) Constant improvement in design of equipment, furnace enlargements, and demands for higher quality of product require not only the extended use of the present available instruments, but also further developments.

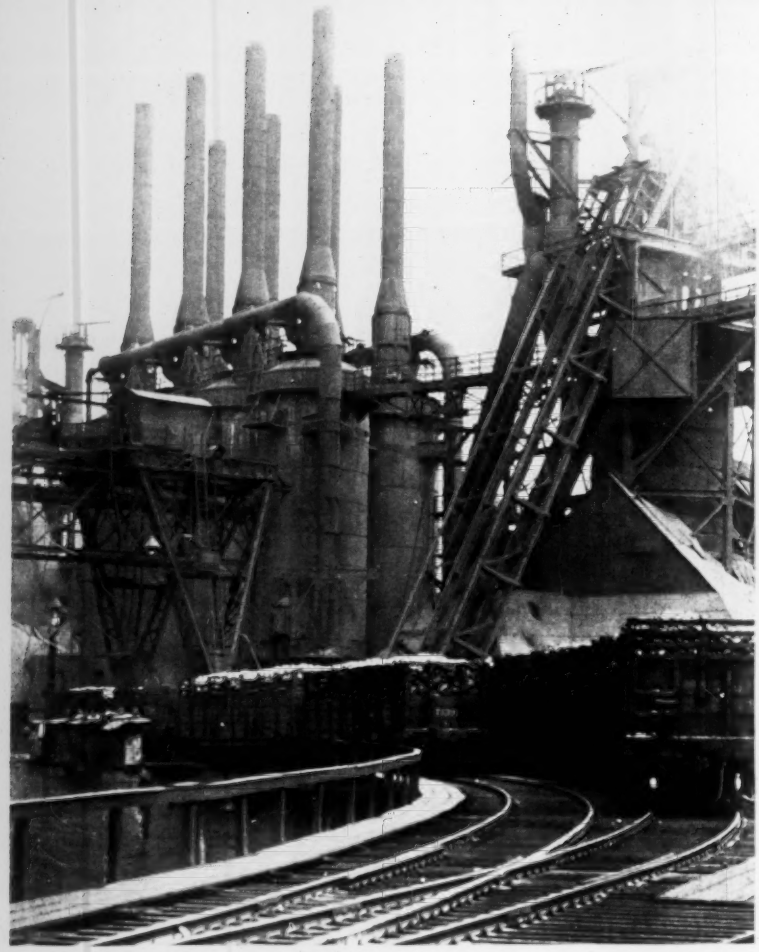
(2) Remarkable progress has been made in the past ten years to make clear the effect of proper gas distribution through the stock on furnace regularity and economy.

(3) Contributions have been made defining other variables, such as iron and slag temperatures to quality, atmospheric humidity, air distribution at the tuyeres, dust content, etc.

The following list of instrument applications includes those which many consider essential to regular and economic operation of a present day plant:

1. Blast temperature
2. Automatic hot blast temperature control
3. Automatic combustion control for stove burners
4. Stove stack temperature
5. Stove dome temperature
6. Stock line recorder
7. Top temperature
8. Blast pressure
9. Top pressure
10. Blast volume
11. Humidity and atmospheric pressure.

No sooner were furnaces equipped with pyrometers for recording hot-blast temperature than furnacemen established the relations between this temperature, the working of the furnace and the quality of the iron. Its acceptance as a guide for furnace control led to the introduction of the hand-operated mixer valve in an effort to maintain a fairly constant blast temperature. Then an alert instrument manufacturer designed an automatic controller to give real "straight line heat." The original scheme has been developed and several manufacturers offer today an accurate and reliable hot-blast recorder-controller. Its primary element is a bare chromel-alumel thermocouple in the hot-blast main not far from the bustle pipe; its final element is a motor operated valve (mixer valve) which permits a part of the cold blast to



by-pass the stove and bleed into the hot-blast main, thus lowering the temperature to the point desired. Temperature requirements will vary from 800° to 1600° F. It is generally conceded that a high hot-blast temperature will reduce the coke rate of the furnace. The silicon and sulphur content of the iron are also affected by variations in the hot-blast temperature. This equipment is especially beneficial, because regularity of stock movement can be benefited materially through quick and accurate control of hot-blast temperature. The maintenance expense of a hot-blast temperature control is slight: replacing the thermocouple every three or four months, changing charts, and periodic checking.

Twenty years ago the majority of our stoves were equipped with aspirating burners. After taking combustion samples, the fuel engineers carefully set and marked the air supply shutters and gas valves. When they returned a few hours later, they usually found altered settings and stoves with poor combustion, failing to supply the required heat for proper furnace operation. The quality of the iron was affected, coke rates were high, and excessive coal was required at the boiler house on account of such practices. The first corrective step was automatic control of gas pressure at the stove burner. This made possible the setting of the air shutters on the burner for proper combustion. Once set by the combustion engineer, the combustion was maintained for a considerable period of time before resetting of the shutters was found necessary. Shortly thereafter the value of hot-blast temperature became recognized. This, together with increased hearth areas, imposed a demand which aspirating burners were unable to meet, and led to the adoption of pressure burners capable of handling larger volumes of gas. In the pressure burner the air is automatically proportioned to the gas (or vice versa) over a wide range of firing rates, with gas and air pressures usually 10″ to 15″ of water. Air pressure may be furnished by central fan for a group of stoves, or (now generally preferred) by individual fans. The control may be operated by oil, air, or electric power. Pressure burners combined with larger stoves, cleaner gas, smaller checker openings, and tangential firing have resulted in higher blast temperatures, more uniform iron, reduced coke rates, and higher stove efficiencies. Improvement in efficiency has been so marked that it is common for stoves to operate on 20% or less of the total gas produced by a furnace, whereas fifteen years ago 40% was not uncommon.

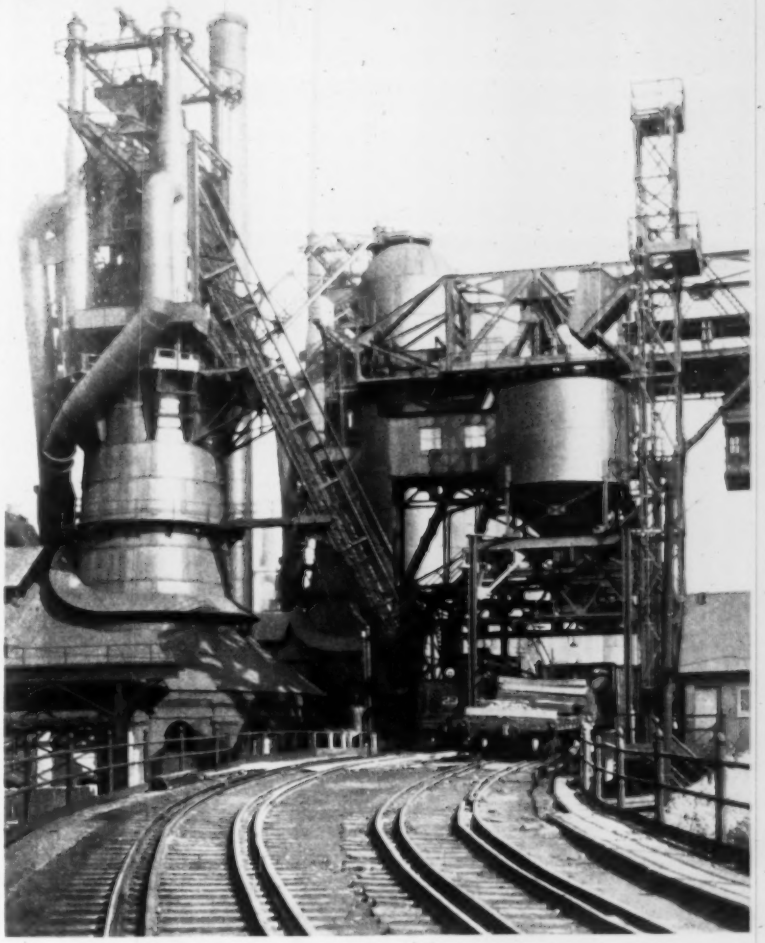
Stove stack temperatures are taken with either a pyrometer or a thermometer. Normally the maximum temperatures range from 300° to 1000° F., depending upon the size of the stove and the heats required. At most plants a recorder is used, for stack temperature is an important measure of the efficiency and operation of the stove. Modern stoves of adequate checker surface are able to maintain low stack temperatures, while those of lower capacity must be pushed to the temperature limit in order to supply the required blast heat. Stack temperature is a measure of the degree of saturation of heat in the checker brick. Experience has taught that certain stack temperatures must be reached before a stove is capable of supplying the heat for various hot-blast temperatures. Fuel losses obviously occur when stack temperatures are carried above requirements. It would be possible to utilize a gas cut-off control similar to those used with open-hearth roof or pit furnace temperature control to eliminate these losses.

A dome temperature recorder as installed on many stoves recently built serves a new purpose by showing the stove combustion chamber temperature. It is a guide to prevent excessive refractory temperature and will show the rapidity with which the stove heats when on gas and loses heat when on air. Together with the stack temperature, it gives a good picture of the heat in the stove.

The history of the stock line recorder is similar to that of the hot-blast control. Originally a test rod was lowered at intervals through a hole in the top of the furnace, outside of the line of bell travel, to determine the height of the stock in the furnace. Later it was found that best performance could be attained when relatively fixed levels were kept. The importance of a recorder became evident: a check on charging would be furnished and any tendency towards irregularities cured without delay. Home-made level recorders of various designs preceded the present automatic electrically-operated recorders. The modern stock line recorder being tied automatically or interlocked electrically with the big bell shows not only the height of the stock and its movement, but frequency or time interval between bell operations. In addition to the recorder, indicators provided with a calibrated column of lamps to show the burden level are usually placed in the cast house for the blower, and in the stock house for the skip operator.

Attention has sometimes been called to the variable in stock distribution introduced by differences in the speed of opening the big bell, which may vary from five to twenty-five seconds with an air- or steam-operated cylinder. This speed is not shown on the stock line recorder, but possibly could be incorporated, or it might be recorded by a separate instrument, with considerable advantage.

Top temperature records (gases leaving the furnace) are carefully watched for indications of furnace irregularities, usually due to improper stock distribution, stock movement, or channeling of the gases through the stock. When top temperatures are not maintained at a fixed



mum by watering the stock, proper charging and proper distribution of gas through the stock, the dust content of the gas rises abnormally, adding to the cost of producing iron. Top temperatures are taken at convenient points such as the downcomer or even in the dust catcher, since from an operating standpoint they are merely relative. Normal temperatures range from 275 to 600 F., depending on location taken, furnace design, burden, and operating practice. Temperatures as high as 800 F. may be encountered on a poorly working furnace. No particular maintenance problem is presented by the normal practice of inserting an iron-constantan thermocouple, protected by an iron tube, into the gas stream.

Probably the first instrument used for the guidance of the furnace operator was a blast pressure gage. Blast and top pressures are both important indices of furnace and auxiliary performance. The blast pressure recorder readily indicates regularity of movement, checks, casts, tuyere changes, etc., and it serves as a general guide of "when" and "what" the furnace has been doing. Variations in top pressure are indications of the rate at which auxiliary equipment is consuming gas when the furnace is operating regularly. When working irregularly, the frequency and severity of slips may be determined from top pressures.

All of the instruments noted above are commonly seen at the modern blast furnace plant. Usually, they are located as conveniently as possible to the cast house. Flush-mounted recorders are often chosen because of their better appearance. Some operators install multiple-point instruments for facilitating comparison and analysis. This avoids confusion when recorders are carelessly set, or when one clock, if mechanical, runs slow or fast. Electric clocks have replaced many of the spring-driven type. Centralization of recorders for groups of blast furnaces has been made for convenience at some plants, with indicators remaining for guidance at the individual furnaces. Some measurements are transmitted to several points, as they concern more than one group of operators; for instance, stock line level indicators both in the cast house and stock house and the recorder in the superintendent's office.

Another measurement essential to proper operation of the blast furnace is the volume of air used for blast. Unfortunately, reciprocating engines preclude the use of a flow meter. Commonly the operation of furnaces so equipped is based on revolutions only. The tub displacement is corrected for some average volumetric efficiency to determine the relative volume of wind blown at various times. The method of determining this volumetric efficiency, or its absolute accuracy, is not a subject for discussion in this article. The revolutions of the engines are variously taken by a stop watch, revolution counter, tachometer, or any combination of these.

When turbo-blowers are employed, the general practice is to install an orifice plate or Venturi tube at the inlet to the blower. The differential may be recorded and integrated on a flow meter and by proper calibration and calculation made to represent volume of wind blown. This differential may also be employed to actuate control apparatus for maintaining any desired rate of blast.

All blast furnace plants are equipped with wet-and-dry-bulb thermometers for determining the humidity of the air, and also a barometer for the determination of atmospheric pressure. It is customary, in order to maintain a constant weight of air delivered to the furnace, to alter the speed of the blower and thereby compensate for changes in atmospheric temperature and pressure. It is also customary to alter the temperature of the hot blast for changes in the humidity of the air. Increased humidity results in increased heat losses in both the stoves and the furnace, as well as changes in chemical reactions within the furnace. The importance of humidity determinations is emphasized when we note that the moisture carried into a 1000-ton furnace with the blast may vary from a low of 72 gallons per hour in the winter to a high of 1100 g.p.h. in the summer. In winter the variation in 24 hours may be from 72 to 432 g.p.h.

The foregoing covers the instruments in general use about a blast furnace, but there are also the laboratory apparatus for analyzing the top gas, the portable Orsat for analyzing waste gases, dust determination apparatus, and sometimes flow meters for the continuous measurement of the top gas. Supplies of electricity, steam, water, fuel gas, compressed air, oxygen, etc., are generally metered continuously, or periodically, to establish checks on operations and a basis for accounting.

While the authors do not intend to discuss all of this apparatus, some discussion of at least part of it is necessary to present the problems which confront the instrument maker of tomorrow.

The value of the fuel gas leaving the top of a 1000-ton furnace is approximately $400,000 per year, with fuel at $3.00 per ton. The need for the most efficient use of so valuable a product requires no emphasis here. Neither is there need to emphasize the effectiveness of accurate metering in economizing the use of any commodity. However, difficulty is usually experienced in metering the quantity of gas leaving the furnace or entering the consuming units. Some of the difficulties are large mains requiring long sections of straight pipe, excessive dust in the gas, various degrees of saturation of the gas, irregularly reduced cross section of gas main due to dust deposits, etc. The plant which can completely meter its blast furnace gas is indeed fortunate. Here is

a fertile field for something entirely new in metering equipment to tax the ingenuity of the best in that field.

Important information required by the combustion engineer in determining fuel economies are the constituents of both the fuel and waste gases. The principal constituents of blast furnace gas are: CO, CO_2, and N_2, with usually a little H_2. It may contain traces of CH_4 and C_nH_m. The CO plus CO_2 usually totals about 40% and the N_2 59%. The average heating value seldom varies outside the range of 88 to 96 B.t.u. per cubic foot. The standard laboratory apparatus consists of explosion and absorption pipettes, a burette, and gas train.

The portable Orsat for determining products of combustion consists of pipettes for the absorption of the CO_2, O_2, and CO which may be present, and a burette. N_2 is determined by difference. Complete combustion lies in the range of 24 to 26% CO_2.

To determine the dust content of the top or fuel gas at some particular point in the system, tests are usually made by inserting a sampling tube into the gas stream and drawing into a filter a metered quantity at the same velocity as exists in the gas main. The dust collected in the filter is dried and weighed. It may vary from 3.0 to 30.0 grains per cubic foot, depending on fineness of ore, watering, rate of blowing, and top design. With this instrument, readings cannot be obtained instantaneously or continuously, and errors are liable to occur by dissimilarity between gas velocities in the main and in the tube. A. W. Simon of the TCI Research Laboratory has developed a system which records light transmission through variations in dust-laden gas. So far as the authors know, this apparatus and other photoelectric systems are not in commercial production. The method offers much promise for the successful solution of one of the most difficult problems in blast furnace instrumentation.

Variations in atmospheric temperature and humidity have a decided effect on the amount of moisture entering a furnace and upon its performance. This was early recognized by Gayley and others who experimented with dry blast. The history of this is well known. Non-adoption of this process was due to lack of proper dehydrating facilities and to cost. With the development of air conditioning and heat-treating during the past several years, improved hygrometers and controls for humidifying and dehumidifying have appeared on the market. Original investment and operating costs are both lower. We may predict that furnaces will yet be operated on seasonal schedules of fixed cold-blast temperature and humidity. This prediction, we feel, is justified because during the period that dry blast investigation was active about seven plants were actually built. Theoretically, Gayley calculated a carbon saving of about 9%. Not only was this exceeded, but there was also a sizeable increase in furnace production and improvement in furnace regularity.

Little attention has been directed to the equal distribution of air to each of the several tuyeres entering the furnace. Operators often suspect irregularities but seem reluctant to introduce a butterfly or restriction, especially in that critical space between the bustle pipe and the blow pipe. Any attempts toward accomplishing equal flow would require metering for each air discharge line. This could be supplemented by an automatic flow proportioner.

For several years before the depression some operators maintained that benefits were derived from temperature measurements taken with thermocouples inserted in the furnace lining at various elevations above the bosh. Four thermocouples were inserted about two feet deep in the brickwork, 90° from each other and on a plane [illegible] distance above the bosh. The couples were connected to a multiple-point recorder. The charts showed at times all temperatures approximately the same, sometimes a difference with lines parallel and at other times the lines crossing one another haphazard. The operator who was interested, but had neither the instruments nor the personnel to study the furnace variables which caused these vagaries, was stymied.

The investigation of the Bureau of Mines at South Chicago, concerning gas flow distribution through the stock, has led to further experimentation and development of the application of cross-sectional temperature and gas analysis measurements for correcting irregularities and economy of operations in blast furnaces. The Inland Steel Co. have erected a special platform around the shell of their new No. 5 Furnace at Chicago to take gas samples and temperatures at certain distances in the stock. A. W. Johnson has published a description of the results from such investigations on several furnaces. It is supposed that the measurements for the present will be secured intermittently with indicating equipment.

The above investigations emphasize the inadequacy of present instruments for continuously determining CO, CO_2, or their ratio, as the Bureau of Mines investigation indicates to be most desirable. Also apparent is the difficulty, if not the impossibility, of obtaining a continuous temperature or gas sample from any fixed point within the stock. If the full benefits of these investigations are to become available to all furnace operators, reliable, rugged, and practical instruments to continuously indicate and record all these variables must be developed.

Studies and investigations have proved the importance of iron and slag temperatures on the regularity of the quality of iron. Variations in the temperature of different casts show a relation of temperature to the sulphur and silicon analysis. Although an optical pyrometer is periodically employed for taking these temperatures, the eye is normally used for such determinations, possibly because of adverse conditions such as fumes. The emissivity factory, too, may be in error due to variations in the chemical composition of different slags. Platinum thermocouples in a double protective tube (the outer one graphite, the inner porcelain) have been used, but these have lasted for only a few readings. The C-SiC thermocouple recently developed by Dr. Fitterer has been used, with many advantages claimed for it over the others commonly used. The U. S. Steel Corp. Research Laboratory has developed and had in service for several months at Gary, Indiana, an instrument employing the Photronic cell for taking steel temperatures in the bath of an open-hearth furnace. Favorable reports have been received on this method.

This article would not be complete without a word concerning the maintenance of the apparatus which we have discussed. The degree of accuracy and the value of the instruments to the operators are a direct function of the respect with which they handle them and the regularity with which they are cleaned and checked. A group of portable instruments for check purposes should be maintained, as should a suitable Instrument Shop for repair, calibration, and stocking of spares. This shop should be well lighted, clean, and free from excessive vibrations or other disturbances. Equipment should include an indicating potentiometer or millivoltmeter, platinum, iron-constantan, and chromel-alumel thermocouples and equipment for same, manometers, test pressure gages, revolution counter, stop watch, standard thermocouples, a test furnace, and standard lamp for testing optical pyrometers.

Rolling Mill Instrumentation

Presented at the Conference on Instrumentation in the Steel Industry, Carnegie Institute of Technology, Oct. 13, 1938

By J. L. WHITTEN

Lee Wilson Engineering Co., Cleveland, Ohio

FUNDAMENTALLY, "rolling mill" temperature instrumentation would start at the soaking pit and from there proceed through the blooming mill, slabbing mill, then to the strip or sheet mill, rod mill, rail mill, or whatever the rolling process; then through the pickling, cold rolling or sizing, annealing, normalizing, or the rest of the special treatments to produce the desired ductility and grain structure in the finished product. However, the application of temperature measuring equipment to rolling or forming processes will be stressed, because these applications are newer and because it is at this point that the ultimate quality of the product is largely determined.

The control of rolling temperatures is the newest thing in the field of mill instrumentation. During the writer's early experience, attempts were made to measure the temperature of steel moving through rolling processes by use of optical and radiation pyrometers which functioned with direct reading galvanometers or balancing potentiometers, but the action was too slow. Naturally, this service requires high speed without over-shooting and, of course, accuracy. The use of photocells and electron tubes to speed the operation of radiation pyrometer equipment pointed the way to the development of equipment which now can, in the case of several manufacturers, record every variation in temperature along the entire length of the bar or billet or slab.

Continuous Strip Mills. On these mills, by reason of the multiplicity of the rolling stands, more equipment is needed per installation and more operations can be governed by the instruments. In this type of installation it is important to take the temperature of the slab as soon as possible after it is free from scale, that is, after number one scale breaker. This is the temperature that enables the furnace operator to reset his furnaces if there are differences in the temperature in the slabs from the various furnaces. Three furnaces may have identical temperature control settings but may be producing slabs at widely different temperatures. This, of course, is basic in consideration of the drafting and metal formation in the rolls and is the first point where uniformity of product can be established insofar as rolling is concerned.

A temperature after two roughing passes enables the operator to change his timing and drafting of the metal and determines the speed at which the next two roughing stands will be operated. After roughing rolling, the temperature at the holding table indicates the time at which the partly formed strip sheet will be sent to the finishing stands and also gages the operation of the last two rules. While instrumentation's control is somewhat negative here—to tell the mistakes of the immediate past operations rather than to maintain a present or future correct processing—the operator uses this information objectively because after the first several slabs are rolled, assuming that the slab temperature is correct to start with, he will be able to set his roll speeds and drafts to bring the material on the holding table at the desired temperature which will allow him to send it to the finishing rolls with little lost time in holding-table cooling.

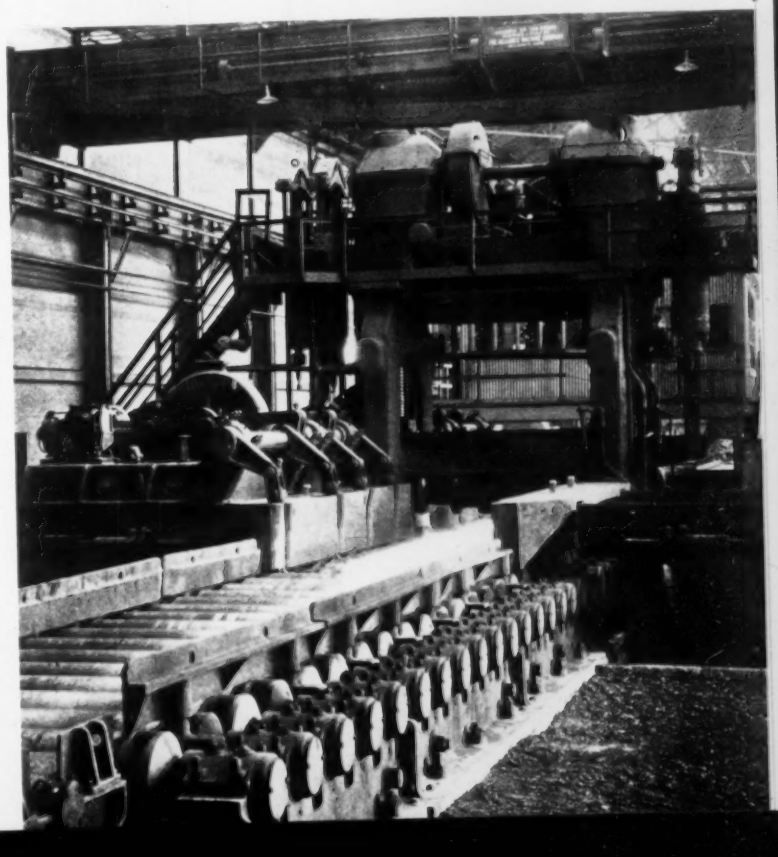
The last check on the rolling operation is the temperature between the last two roll stands or after the last pass. While it is desirable to take the actual finished temperature of rolling (after the last pass) in some cases the finishing temperature has been too near the lower end of present instrument scale ranges to allow for the accuracies desired, and therefore this point has been moved back between the last two roll stands. However, recent developments are removing this objection.

The temperature of the holding table and the temperature after the last pass determine the finishing mill speed and drafting. Since it is this temperature that has such a formative effect on the final metal structure and its requirements on annealing, normalizing, and temper passing, it is most important that the mill speeds be set so that with the desired temperature at the holding table the material will finish at the desired temperature when it leaves the rolls.

Some mills have advantageously employed a further and final check, by taking the temperature of the strip at the coiler. This temperature is apt to be low and the metal quite black, but the metallurgical departments, by knowing this temperature, have often been able to adjust the following treatments to produce first quality material which otherwise might have been seconds or scrap.

This rather detailed description of one process was given because it largely predicts the application to others. Of course, many processes require fewer points of control; some require only one. Brief comments on some of the installations may serve as a guide.

Merchant Mills. This class, up to say 14" size but used largely for the production of rods and bars of various shapes, has been controlled quite successfully by taking the temperature after the finishing pass of the mill. The sighting gun usually can be placed only in a horizontal position and has to be adjusted to sight on a rather small target: the side of the piece which in most cases is not thicker than 2". Satisfactory calibrations



have been made with a sighting shutter to limit the field at which the sighting piece can be pointed. With this arrangement, on bars which roll 200 feet in length to finish every furnace burner location could be adjusted to produce uniform initial heating.

Blooming Mills. A satisfactory point of measurement has been with the sighting piece placed horizontally looking through a hole cut in the side of the mill guides so as to be sure to get the temperature of the bloom after every other pass as it is progressively worked through the mill. A disadvantage is that the side presented to the target has had some time to allow for scale formation, but in the writer's experience no installation has been made where the temperatures are taken from the top of the mill down on the bloom on account of the difficulty in developing an apparatus to keep the gun sighted on its target.

Pipe Welding Mills. The last statement in the previous comment suggests a discussion of equipment for taking temperature of welded pipe, because equipment has been successfully worked out in which the sighting target moves to follow the welding roll positions in lap-weld mills where the mill alternates between two positions. In this case the sighting gun was mounted on a trunnion and accurately positioned by stops so that the mill movement pulled the gun into exact position to follow it. Rectangular orifice plates were used to limit the sighting field to the welding band on the pipe, as this was the point from which the furnace temperature was to be governed.

Rail Mills. A number of installations have been made using one point of temperature measurement: after the final sizing roll. This temperature is useful not only for governing the rolling, but in order to govern the temperature which must be reached before the rail is sawed to length.

Wire Rod Mills. This application has taxed the ingenuity of designing engineers, because the targets in many cases were no larger in diameter than $\frac{3}{8}$". Here again this has been accomplished by the use of limiting orifices. In most cases two sighting guns have been used, one to take the temperature of the bar immediately after the second roughing pass and the other to take the temperature of the finished rod as it leaves the final finishing roll. Another point of measurement is taking the temperature of the rods as they are reeled into coils, much in the same manner of application as mentioned under continuous strip mills.

Seamless Tube Mills. In this type of installation the temperature has been taken after the first piercing operation when the pierced tubes leave the mill practically scale free. Some mills have taken temperatures farther along in the sizing and re-heating operations in order to make sure that the metal was of a temperature for correct flow to final size, but apparently it is the thought of most mills that the temperature of the steel taken as soon as it is scale free determines the final quality of this rolling operation.

This discussion could be carried further into numerous other installations, but the detail of each would largely be the same, and there are always local conditions which change the type of installations. However, this discussion will establish that the art of temperature measurement of fast moving hot bodies is well developed, and no rolling mill operator should hesitate to install this type of equipment. In fact, this art is so well developed that thought is being given to the ultimate control of mill speeds and mill drafts from rolling temperatures and the automatic resetting of heating and soaking zone temperatures from rolling temperatures. The writer has just concluded patent applications for these processes.

DUAL CONTROL

Originally, dual control was developed for electrically heated pot furnace work, with the idea of limiting the temperature developed by the electric heating elements and of restraining the effect of the lag created by the differences in temperature between the elements and the work. The advent of the radiant tube fired furnace with its metallic firing tubes necessitated a check on the tube temperatures. There are other applications as in soaking pits, where dual control is necessary for roof protection as well as steel protection. It is my intention to discuss its application to radiant tube fired furnaces because it was my privilege to develop this type of control. Some 65 or 70 installations have been made, most of them on Lee Wilson furnaces.

The basic principle is to control the tubes to limit them until the steel has reached its control point, and at that time to switch over automatically from the tube thermocouple to the steel thermocouple and maintain the desired steel temperature while the tubes continue to fall in temperature during the soaking part of the cycle. This first was developed with two instruments and then combined into one which, in addition to the features outlined above, allows the control to re-cycle or revert to tube temperatures if for any reason the tubes become excessively hot. This re-cycling can function indefinitely as long as it is necessary for a transfer of control point. Above all of the control functions, an extra limit was placed to either cut the fuel to a minimum position or shut it off entirely if this limit were reached. On large furnaces this limit may be worked from several points near the tubes.

This control has been designed to function with a proportioning control mechanism to allow the full benefit of the diminishing radiant column in the firing tube to be applied to the charge so that the curtain of heat around the charge is gradually lowered as full penetration and uniformity are developed.

ATMOSPHERE CONTROL

There have been similar improvements in all phases of rolling mill instrumentation, and we could not leave this subject without reference to atmosphere regulation.

For furnaces of the batch type in which the charge can be protected by an inner hood, a definite atmosphere can be prepared. There is equipment available which can be used to run a continuous analysis on the reducing properties of deoxidizing gases to determine constancy in analysis and to serve as a check on the machines generating these atmospheres.

On direct-fired furnaces, atmosphere analysis equipment is found as useful where it directly registers the quality of the gases in immediate contact with the steel as created by active combustion in the furnace, and by progressive zone analysis certain areas in the furnace which are producing atmospheres damaging to the steel surface can be isolated and then corrected.

With the idea of applying this apparatus to automatic regulation, several companies have been experimenting for the past several years; so, in the not too distant future it should be possible to obtain equipment which will automatically regulate furnace atmospheres on a definite program to provide different types of atmosphere at different times during the heating cycles.

Rebound Methods of Measuring Hardness

By S. R. WILLIAMS
Professor of Physics, Amherst College

EXPERIMENTAL DETERMINATION OF e

When various materials are in the form of spheres it becomes a simple laboratory experiment to measure their coefficients of restitution. Steel balls, glass marbles and ivory balls fulfill these conditions. Fig. 174 shows a simple outfit for performing the experiment. The balls are dropped from a height h_2 onto the hardest possible flat surface, B. (A blacksmith's anvil makes a good surface.)

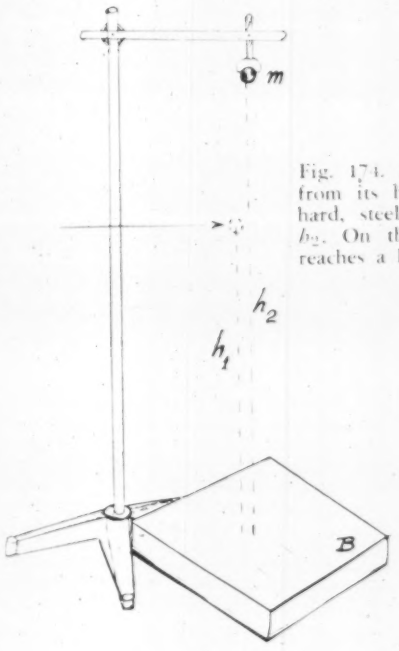


Fig. 174. A steel ball m falls from its holder to the heavy, hard, steel base B, a distance h_2. On the rebound the ball reaches a height h_1.

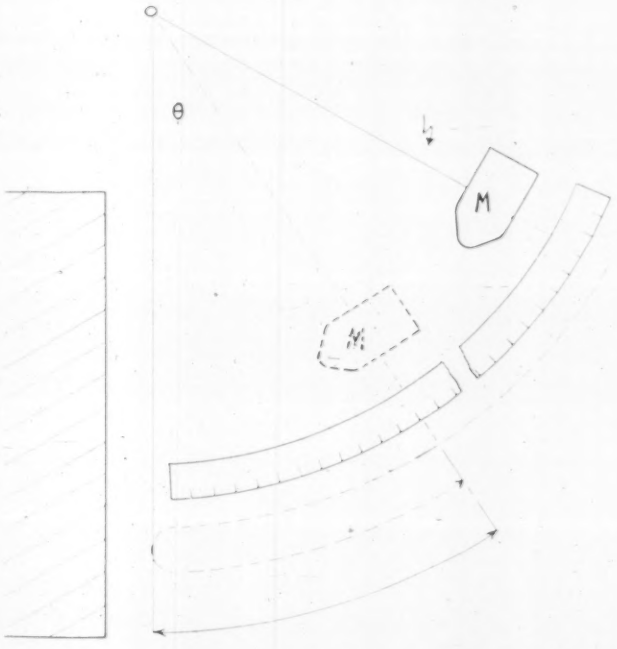


Fig. 175. Pendulum Recoil Test. θ is the angle of recoil. This is a modified form of the device shown in Fig. 174.

When the ball strikes the anvil it rebounds upward from the anvil to a height h_1. Inasmuch as the velocity v of a body falling freely through space is equal to the square root of the product of twice the acceleration of gravity by the height which it has fallen, the relations are as follows:

$$e = v_1/v_2 = \sqrt{(2gh_1/2gh_2)} = \sqrt{(h_1/h_2)}$$

Fig. 174 shows how the experiment is performed. The ball is held in a clamp and the distance h_2 from the bottom of the ball to the surface B is measured. When released the ball falls and makes an impact on B and then rebounds to a height h_1. The latter may be measured by sighting the bottom of the ball against a meter stick set on end behind the path of the ball. This experiment may also be worked out with the steel, glass and ivory balls suspended as pendulums and allowed to swing against a solid surface or against a similar ball. Fig. 175 shows the outfit in schematic design.

THE SHORE SCLEROSCOPE

This instrument is the most widely used of all the rebound machines for measuring hardness. Fig. 176 shows the Shore Standard Dial Recording Scleroscope, Model D-1. The principle employed is the drop and rebound of a diamond tipped hammer in which the rebound becomes a measure of the hardness of the material on which the hammer struck. The rebound is read from the graduated scale on the dial shown in Fig. 176.

The Shore Scleroscope embodies portability as well as being a set instrument for the shop and laboratory. The main part of the outfit as shown in Fig. 176 may be detached from its regular massive base and used on a special base with a long swing arm as shown in Fig. 177, so that it may be employed on specimens too large to be brought under the hammer on the regular instrument.

Also the main part of the scleroscope may be used as a strictly portable machine as shown in Fig. 178 where it is held free handed by the ring R. Specimens which cannot be brought into the shop or laboratory can, by means of this arrangement, be measured in the field.

Fig. 179 shows the portable part of the scleroscope in cross sections, both for the front and the side views. The heart of the instrument is the diamond tipped hammer shown in Fig. 180 and designated as F in Fig. 179. This hammer consists of a steel bar whose overall length is 10.16 cm. The mass is 36.810 g. One end of the steel cylinder is reduced in diameter and into the end of this smaller section is ground a carefully tapered hole into which is forced a diamond tapered to the same degree. In this way the diamond is held rigidly as it receives the jolt of the falling hammer. Figs. 181 and 182 show close-ups of the diamond.

The hammer falls from a fixed height and when it strikes a metal surface, a small indentation is made like the one in Fig. 183. The hammer, however, rebounds and jumps upward again, but not to its original height because some of the energy of the falling hammer has been dissipated in producing the permanent deformation shown in Fig. 183. The height of the rebound as indicated on the dial in Fig. 176 is taken as a measure of the hardness

[3] R. A. Millikan, Mechanics, Molecular Physics and Heat, Ginn & Co., Boston, 1903. Page 61.

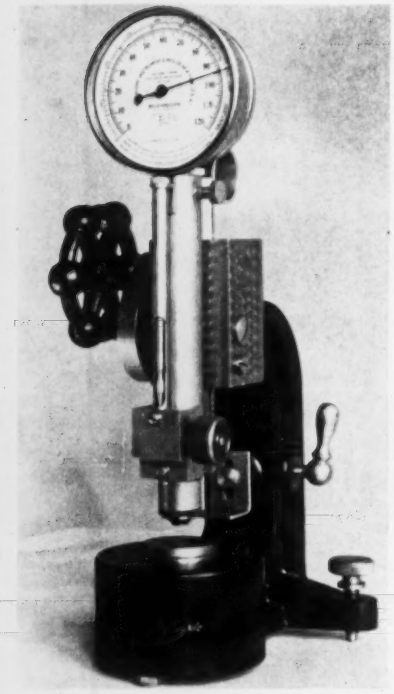


Fig. 176. Shore's Standard Dial Recording Scleroscope. Portable Model D-1. Dial shows Brinell and Shore numbers.

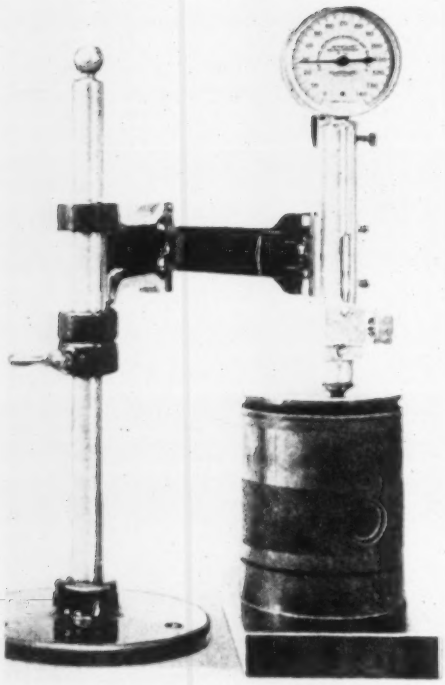


Fig. 177. Shore's Model D-1 Scleroscope used on a special base and swing arm for testing large pieces on the bench.

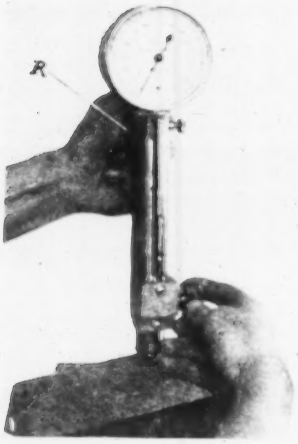


Fig. 178. Model D-1 Scleroscope detached from its regular base and used free-handed by gripping ring R.

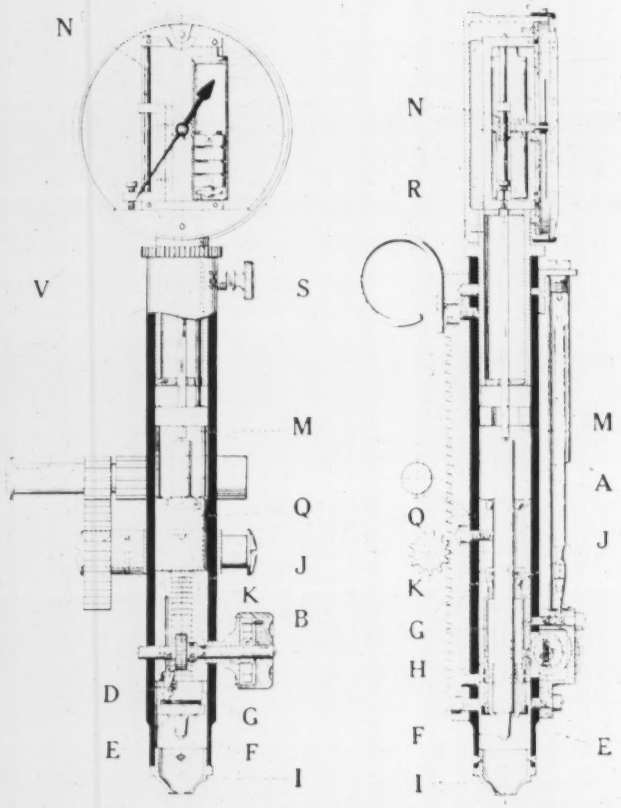


Fig. 179. Front and side longitudinal section of the mechanism which elevates and releases the hammer; and section of registering device.

Fig. 180. The hammer whose rebound is measured in determining the hardness of metals with the Shore Scleroscope.

Fig. 181. The cone shaped diamond inset on the hammer of the Shore Scleroscope.

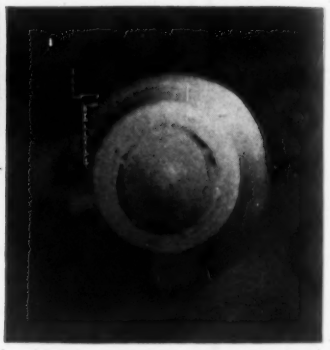


Fig. 182. The cone-shaped diamond of the hammer. End view.

because the amount of rebound is proportional to the resistance which the diamond point meets in making the permanent deformation. Actually "the scale against which the hammer rebounds are measured, consists of units which are determined by dividing the average rebound from quenched pure high carbon steels into 100 equal parts. These rebounds run from 95 to 105 divisions." The scale is continued higher than 100 to include metals having exceptionally high or superhardness.

Fig. 184 shows the indentation made by the Rockwell Hardness Tester in the same piece of brass as was that in Fig. 183. It will be noted that because the steel ball has a much smoother surface than the diamond point in Figs. 181 and 182, the bottom of the imprint in Fig. 184 is much smoother than the one in Fig. 183. The latter shows an extraordinarily rough surface and no sharp line around the imprint as in Fig. 184.

The device whereby the hammer is tripped off at a definite height above the surface of the specimen and then on rebound to have its height registered is a most ingenious arrangement. This is fully described in an 80-

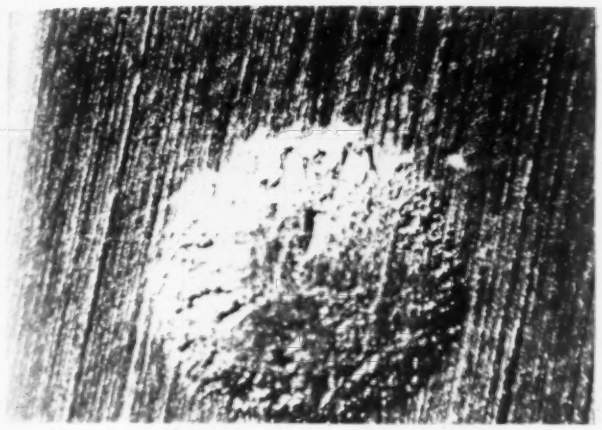


Fig. 183. The indentation made by the diamond point of the hammer as it strikes a surface of brass, Rockwell Number B. 82.5—84.5

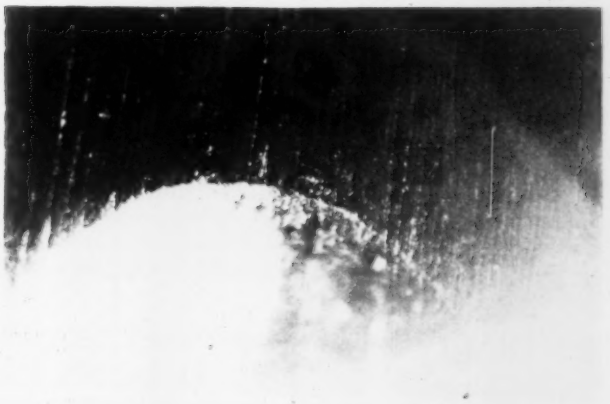


Fig. 184. The indentation made by the steel ball of the Rockwell Hardness Tester on a standard brass plate B. 82.5—84.5

page booklet put out by the manufacturer and there is no need to go into a detailed account here.

Like all so-called hardness testers the numbers read from the dial indicator of the instrument are purely relative, and yet they show relative values of something that makes it a useful instrument for measuring the suitability of materials for certain definite purposes.

In Fig. 26 (April 1937 instalment) were shown the relations between Brinell numbers and tensile strengths for a wide range of steels. These values were taken from tables furnished by the Heppenstall Co. in a booklet entitled "Effects of Alloying Elements and the Physical Properties of Steel in Forged Sections." Fortunately, the same company has published a series of hardness conversion tables in this booklet and also give the Shore Scleroscope numbers for the same steels as were shown in Fig. 26. The relations between the Shore Scleroscope numbers and the tensile strengths of certain steels are shown in Fig. 185. It will be seen that the Shore Scleroscope numbers are not quite so directly proportional to tensile strength as were the Brinell numbers and yet do afford a relationship of value in measuring suitability of materials.

The claim made for the Shore Scleroscope is that its one scale covers the whole range of metals from the softest to the hardest. While this may be true for metals,

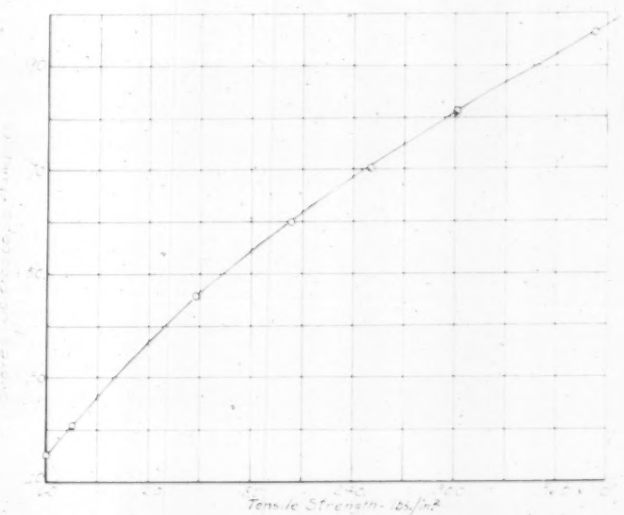


Fig. 185. Compare this figure with Fig. 26 (April 1937).

the question arises: what is to be done with substances other than metals? For instance, a brass block reads 31.0 on the Shore Scleroscope, but some of the modern plastics give readings twice as high, and yet we know that the brass is harder. In the case of the plastics most of the rebound is due to resilience. This point will be discussed later in a chapter devoted to the hardness of substances other than metals. The insistence must be maintained that metallurgists are not alone concerned in the hardness of things.

The metal that holds the diamond and even the diamond itself may vary in its coefficient of restitution. It therefore becomes necessary when standardizing the hammer to alter slightly the radius of the striking point. In this way the instruments are standardized to read all alike on the same master block.

For some time it has appeared to the author that the rebound principle had a great deal of merit when used in connection with the measurement of hardness. There is, however, a need for further investigation of the principle. As indicated in connection with scleroscope tests on plastics, the height of rebound itself does not give a direct indication of hardness. It is not always true that the higher the rebound the harder is the material. The specimen may be of such a quality that it will not take a permanent set. There is a probability that if a study were made of both the volume of the indentation and the rebound a combination of the two might show a definite relation to hardness. It is along such lines that the author hopes to get relative values of the hardness of the various glasses which are now on the market. The term "glass hard" takes on a new meaning to one who has attempted to measure the hardness of glass by existing methods.

Over 40 years ago Martel[2] showed that the volume of indentation produced by the falling-hammer is proportional to the height of fall and the mass of the hammer; and independent of its shape. Furthermore, Edwards and Willis[3] showed that there is a definite relation between the impact indentation test and the static indentation test (Brinell); and that there is a definite relation between the resistance to penetration offered by metals and the energy spent in producing that indentation. Finally,

[2] R. Martel, Impact Testing of Hardness (Commission des Methodes d'Essai des Materiaux de Construction, Paris, Vol. 3, 1895, Sec. A, Metals, page 261).

[3] C. A. Edwards and F. W. Willis, A Law Governing the Resistance to Penetration of Metals when Tested by Impact with a 10-mm. Steel Ball, and a new Hardness Scale in Energy Units (Proceedings Institution of Mechanical Engineers, Vol. 82, 1911, pages 33-46).